Migrating Legacy Services to MPLS

An MPLS & Frame Relay Alliance Sponsored Half Day Tutorial

Agenda

- Section 1: Introduction to the MPLS & Frame Relay Alliance
- Section 2: Strategy Overview
  - ✓ Today's Networks
  - ✓ Key Requirements and Challenges
  - ✓ Alternative Solution Architectures
  - ✓ Why MPLS
- Section 3: MPLS Overview
  - ✓ MPLS Network Solution Overview
  - ✓ Topology Determination
  - ✓ Labels & Label Distribution
  - ✓ Differentiated Services – Diffserv
  - ✓ Dealing with Contention
  - ✓ Network Resiliency
  - ✓ LDP Extended Discovery
  - ✓ MPLS PVC UNI
- Break
- Section 4: Migrating Frame Relay and ATM to MPLS
  - ✓ Current Frame Relay/ATM Network Solutions
  - ✓ Integration Strategies: Motivations and Solutions
  - ✓ ATM/FR-MPLS Solution
  - ✓ Frame Relay-MPLS Solution
  - ✓ Summary
- Section 5: Migrating TDM and Voice to MPLS
  - ✓ TDM over MPLS
  - ✓ Voice over IP
  - ✓ Voice over MPLS
- Tutorial Summary

Contributors

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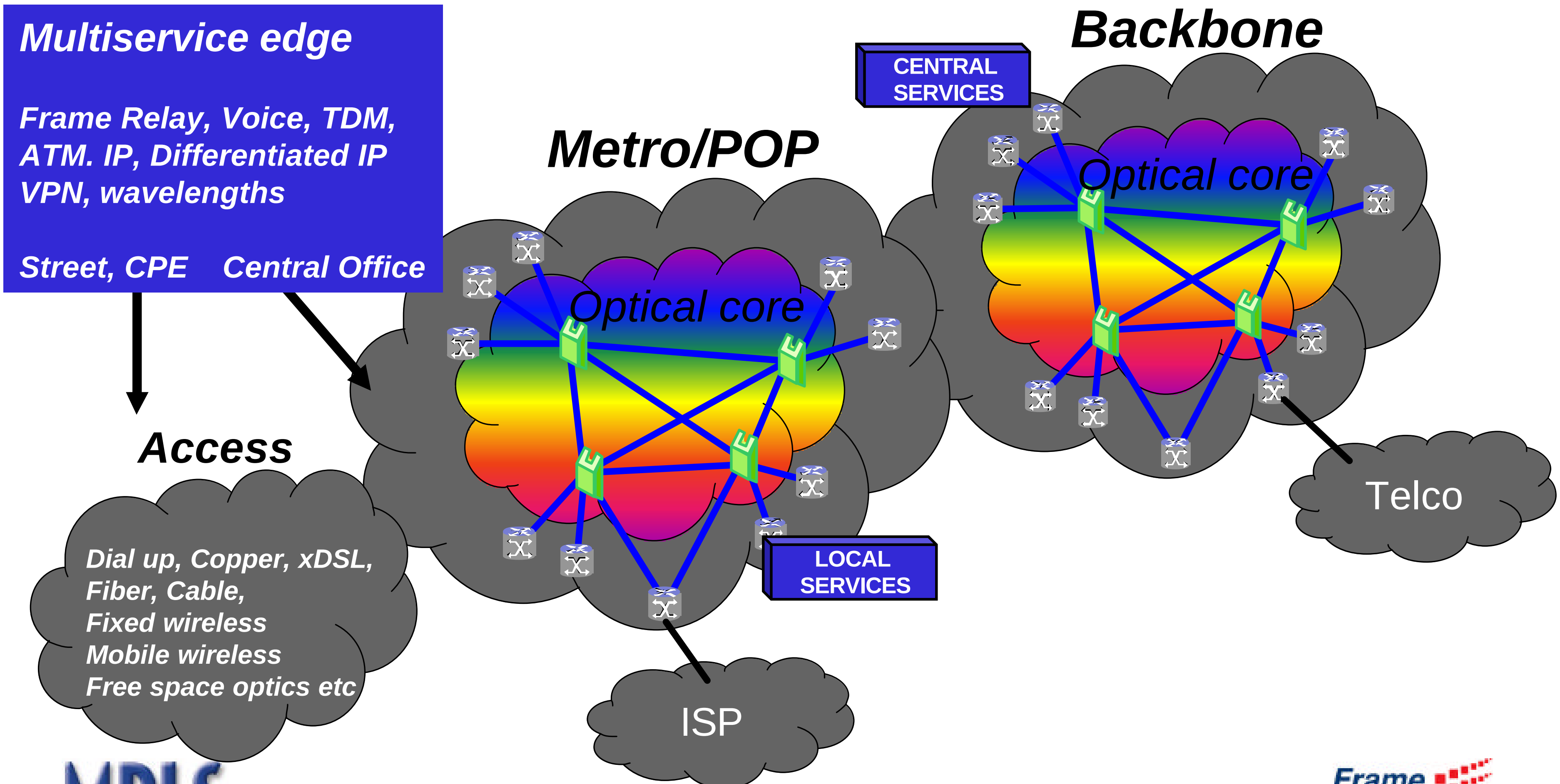
Introduction to the MPLS & Frame Relay Alliance

http://www.mplsforum.org/ http://www.frforum.org

MPLS/FR Alliance

An industry-wide association of networking and telecommunication companies focused on advancing the deployment of multi-vendor multi-service label switching networks and associated applications.

Converged Network Vision



MPLS & Frame Relay Alliance Information and Membership

- Founded April 2003 by merging the MPLS Forum and Frame Relay Forum
- Combined vision of FR access to MPLS in the core
- 56 members as of July 2003
- Three primary committees
  - ✓ Marketing Awareness and Education (MAE) Committee
  - ✓ Technical Committee
    - Applications and Deployment Working Group
    - Frame Relay Working Group
  - ✓ Interoperability Committee

Board of Directors

- Previous meeting: Vienna VA, July 2003
- Current meeting: London England, October 2003 (co-located with ATM and BCD Forums)
- Next meeting: San Diego, January 2004

Alliance Leadership Positions

- Board members
  - ✓ Bernard da Costa, Bell Canada, Board Member
  - ✓ Joe Kimball, Sprint, Board Member
  - ✓ Gary Leonard, Riverstone Networks, VP of Marketing
  - ✓ Andrew Malis, Tellabs, Chairman and President
  - ✓ Doug O'Leary, Verizon, Treasurer
  - ✓ Ananda Sen Gupta, Agilent Technologies, Vice Chairman, International Development
  - ✓ David Sinicrope, Ericsson, Secretary
  - ✓ Rick Wilder, Consultant
  - ✓ Tom Walsh, Lucent Technologies, Vice Chairman
  - ✓ Ex officio: David Drury, Accipiter Systems, President Emeritus

Alliance Leadership Positions

- Technical Committee
  - ✓ Rao Cherukuri, Cisco Systems, Co-Chair
  - ✓ Dr. John Yu, Hammerhead Systems, Co-Chair and Frame Relay Working Group Chair
  - ✓ Jarrod Siket, Marconi, Vice-Chair
  - ✓ David Sinicrope, Ericsson, Applications and Deployment Working Group Chair
  - ✓ Nikhil Shah, Lucent Technologies, A&D WG Vice Chair
- Marketing Committee
  - ✓ Gary Leonard, Riverstone Networks, Co-Chair
  - ✓ Roger Ruby, Quick Eagle Networks, Co-Chair
  - ✓ Sunil Khandekar, TiMetra Networks (soon to be Alcatel), Vice Chair
  - ✓ Kimberly Booth, Laurel Networks, Press Relations Working Group Chair
  - ✓ David Christophe, Lucent Technologies, Education Working Group Chair
- Interoperability Committee
  - ✓ Ananda Sen Gupta, Agilent Technologies, Chair
  - ✓ Mark Dyga, Laurel Networks, Vice Chair

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Published Frame Relay Forum Implementation Agreements

- FRF.1.2, PVC User-to-Network Interface (UNI) Implementation Agreement, July 2000
- FRF.2.2, Frame Relay Network-to-Network Interface (NNI) Implementation Agreement, March 2002
- FRF.3.2, Frame Relay Multiprotocol Encapsulation Implementation Agreement, April 2000
- FRF.4.1, SVC User-to-Network Interface (UNI) Implementation Agreement, January 2000
- FRF.5, Frame Relay/ATM PVC Network Interworking Implementation, December 1994
- FRF.6.1, Frame Relay Service Customer Network Management Implementation Agreement, September 2002
- FRF.7, Frame Relay PVC Multicast Service and Protocol Description, October 1994
- FRF.8.1, Frame Relay / ATM PVC Service Interworking Implementation Agreement, February 2000
- FRF.9, Data Compression Over Frame Relay Implementation Agreement, January 1996
- FRF.10.1, Frame Relay Network-to-Network SVC Implementation Agreement, September 1996
- FRF.11.1, Voice over Frame Relay Implementation Agreement, March 1999
- FRF.12, Frame Relay Fragmentation Implementation Agreement, December 1997
- FRF.13, Service Level Definitions Implementation Agreement, August 1998
- FRF.14, Physical Layer Interface Implementation Agreement, December 1998
- FRF.15, End-to-End Multilink Frame Relay Implementation Agreement, August 1999
- FRF.16.1, Multilink Frame Relay UNI/NNI Implementation Agreement, May 2002
- FRF.17, Frame Relay Privacy Implementation Agreement, January 2000
- FRF.18, Network-to-Network FR/ATM SVC Service Interworking Implementation Agreement, April 2000
- FRF.19, Frame Relay Operations, Administration and Maintenance Implementation Agreement, March 2001
- FRF.20, Frame Relay IP Header Compression Implementation Agreement, June 2001

Published MPLS Forum Implementation Agreements

- **MPLS Forum 1.0: Voice over MPLS – Bearer Transport, July 2001**
- **MPLS Forum 2.0.1: MPLS PVC User to Network Interface, May 2003**
- **MPLS Forum 3.0: LDP Conformance Test Plan, December 2002**
- **MPLS/FR Alliance 4.0: TDM Transport over MPLS using AAL1, June 2003**
- **MPLS/FR Alliance 5.0: I.366.2 Voice Trunking Format over MPLS, August 2003**

Market Awareness & Education

- Tutorials
  - ✓ MPLS Introduction — full day
  - ✓ MPLS Virtual Private Networks — ½ day and full day
  - ✓ Traffic Engineering — ½ day
  - ✓ GMPLS — ½ day
  - ✓ VoMPLS — ½ day
- ½ day tutorial debuted in February 2003
  - ✓ Legacy Service Migration to MPLS (FR, ATM, TDM, Voice)
- New tutorials based upon demand
- Conferences and exhibitions
  - ✓ Almost every MPLS conference globally has had an Alliance speaker
- Website and Newsletter
  - ✓ In January 2003, new website and newsletter were launched
- Public message board debuted September 2003

Interoperability Committee

- Conformance Test Plans
  - ✓ LDP - Completed, now published as MPLS Forum 3.0
  - ✓ RSVP-TE – Completed straw ballot, approved by TC for BoD review prior to Final Ballot
- Interoperability Test Plans
  - ✓ LDP – To be sent to Straw Ballot at Virginia meeting
  - ✓ RSVP-TE - To be sent to Straw Ballot at Virginia meeting
  - ✓ BGP/MPLS VPNs - to be sent to Straw Ball at Virginia meeting
  - ✓ L2oMPLS (Martini/PWE3) - modifications to reflect recent changes and detailed test cases
  - ✓ Virtual Private LAN Service (VPLS), Fast Reroute (FRR) – work continuing on test plans

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Technical Committee

- **MPLS Multiservice Core**
  - ✓ Enables service providers a migration path to MPLS
    - Tunnel legacy services over MPLS
    - Network and Service Interworking
  - ✓ Builds upon and conforms to IETF PWE3 and PPVPN and ITU-T SG 13 work
    - Fills in "missing pieces" and/or provides source material
- **MPLS Service Edge**
  - ✓ MPLS UNI
  - ✓ MPLS/PNNI signaling interworking
  - ✓ Interworking between FR, ATM, and Ethernet over MPLS networks
  - ✓ FR/MPLS network interworking (joint work with ITU-T Study Group 17)

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Technical Committee Work Items

Technical Committee Work Item & Description	Target Straw Ballot*	Target Final Ballot*
PNNI/MPLS Interworking This allows signaling service interworking between ATM and MPLS networks, by translating between ATM PNNI signaling as defined by the ATM Forum and MPLS LDP signaling as defined by the IETF.	Aug 2003 (issued)	Jan 2004
MPLS UNI LSP Connection Service Definition Definition of native MPLS LSP transport service.	Aug 2003 (issued)	Jan 2004
FR/MPLS Network Interworking Frame relay to frame relay service offered using MPLS as a backbone transport. Both 1:1 as well as Port mode.	Oct 2003	Jan 2004
UNI QoS Proxy Admission Control Service Definition Definition of a service provided on the MPLS UNI that allows a CE to request resources of the provider network.	Oct 2003	Jan 2004

* Dates subject to change

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Technical Committee Work Items

Technical Committee Work Item & Description	Target Straw Ballot*	Target Final Ballot*
UNI QoS Proxy Admission Control Protocol UNI protocol modifications to support the UNI QoS Proxy Admission Control Service Definition	Oct 2003 (issued)	Apr 2004
ATM/FR/Ethernet Service Interworking Transport of ATM, Frame Relay and/or Ethernet over MPLS without requiring the same service on both ends of the connection.	Oct 2003	Apr 2004
SONET over MPLS Implementation specification for transport of SONET/SDH over MPLS	Jan 2004	Jul 2004
HDLC over MPLS Implementation specification for transport of HDLC over MPLS	Jan 2004	Jul 2004

* Dates are subject to change

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Relationships with Other Bodies

- **IETF**
  - ✓ Alliance work based on IETF RFCs and/or ITU-T Recommendations
  - ✓ Only do work that does not fit in IETF charter, such as MPLS test plans, PNNI interworking, VoMPLS, etc.
  - ✓ Strong common participation between IETF and Alliance
- **ITU-T**
  - ✓ Achieved A4 and A5 liaison status with ITU-T
  - ✓ Communicating with Study Groups 11, 13, 15, and 17 regarding such topics as MPLS OAM, MPLS/PNNI signaling interworking, VoMPLS carriage and signaling
- **ATM Forum**
  - ✓ In October 2001, began a program of joint conference calls
  - ✓ Held co-located meetings in January and July 2003, more co-located meetings planned
- **Metro Ethernet Forum**
  - ✓ Jointly announced a formal liaison relationship, working in concert on FR/ATM/Ethernet interworking

Public Interoperability Events

- **SUPERCOMM (Atlanta), June 2002**
  - ✓ MPLS traffic engineering, Layer 2 and 3 Virtual Private Networks (VPNs)
- **Next Generation Networks (Boston), October 2002**
  - ✓ Generalized MPLS (GMPLS)
- **MPLS World Congress (Paris), February 2003**
  - ✓ BGP/VPN Scalability, MPLS Fast Reroute (FRR)
- **SUPERCOMM (Atlanta), June 2003**
  - ✓ Frame Relay, ATM, Ethernet/VLAN over MPLS, Virtual Private LAN Services (VPLS), MPLS Fast Reroute (FRR)
- **Upcoming: MPLS World Congress, Paris, February 2004**

Summary

- Frame Relay is a $15B/year industry, still growing at 20%/year
- MPLS is now a proven success (over 200 known service provider deployments)
- MPLS in widely use for traffic engineering
- New MPLS applications (VPNs, QoS, multimedia) are undergoing development and deployment
- Interoperability and conformance testing continue to be crucial as new applications are standardized
- The MPLS & Frame Relay Alliance has a key role in MPLS and FR development
- Please join us!

Alliance Rights of Membership

- Attendance at all Alliance Meetings
- One vote on all Alliance ballots
- Submit contributions for Alliance work items
- Access to all documents, minutes & e-mail
- Access to all education materials
- Run for the Board or Chair positions
- Discounts to many MPLS conferences

How to Join the MPLS & Frame Relay Alliance

- Fill out a Membership Application Today
  - ✓ Download from the Alliance Web Site
  - ✓ http://www.mplsforum.org/
- Contact Alexa Morris, Executive Director
  - ✓ E-Mail amorris@mplsforum.org
  - ✓ Phone 510-608-5914
- Subscribe to Info Mail List
  - ✓ info@mplsforum.org

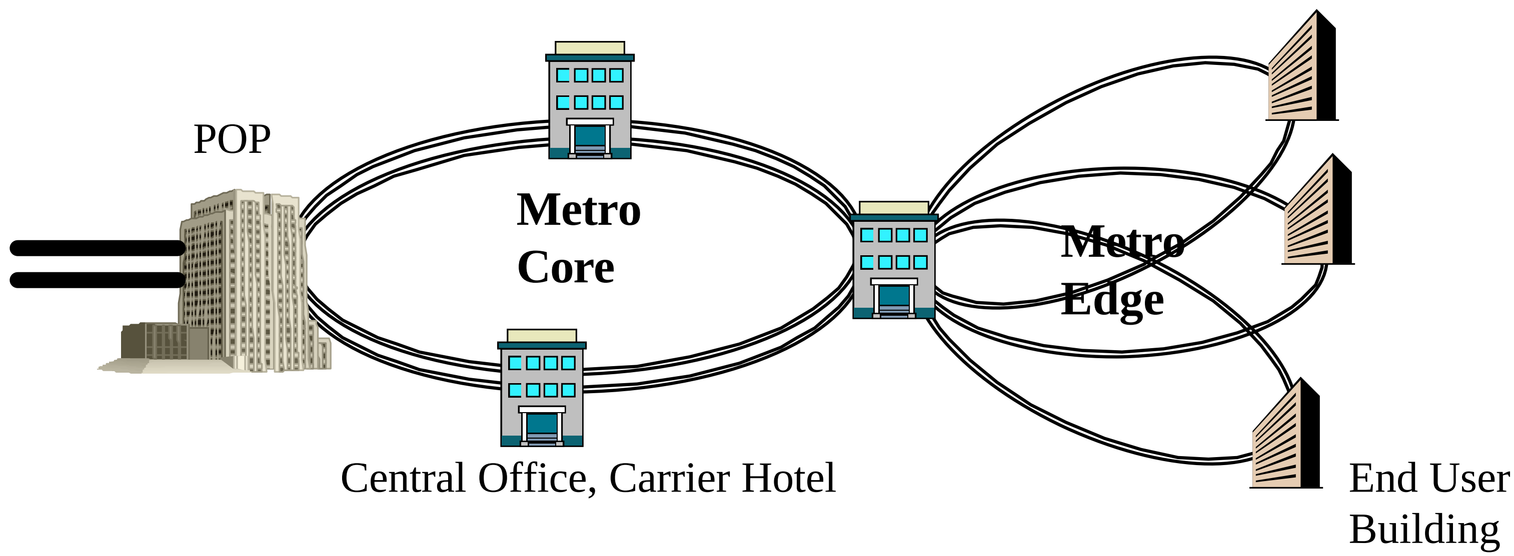
Overview of the Strategy

Section 2

Agenda

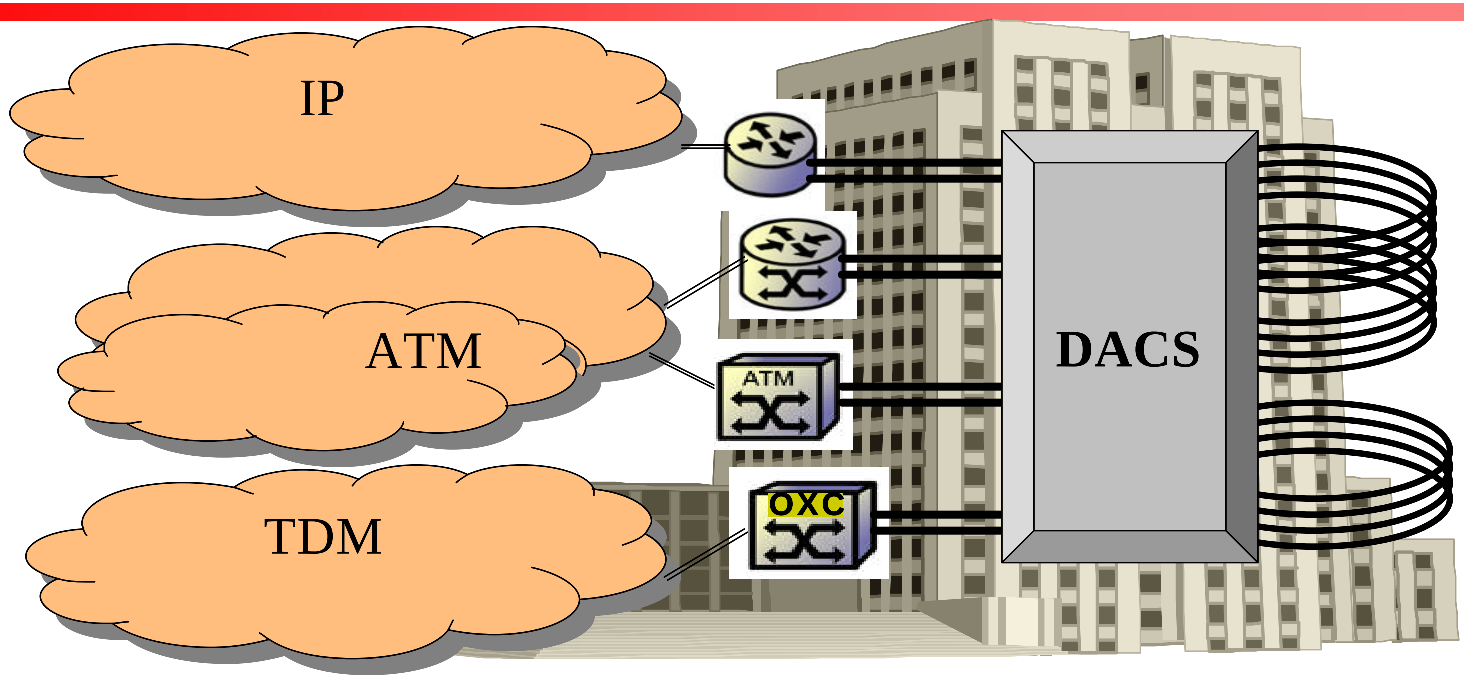
- **Today's Networks**
- **Key Requirements and Challenges**
- **Existing Networks Limitations**
- **Alternative Solution Architectures**
- **Why MPLS**

Today’s Metro Network



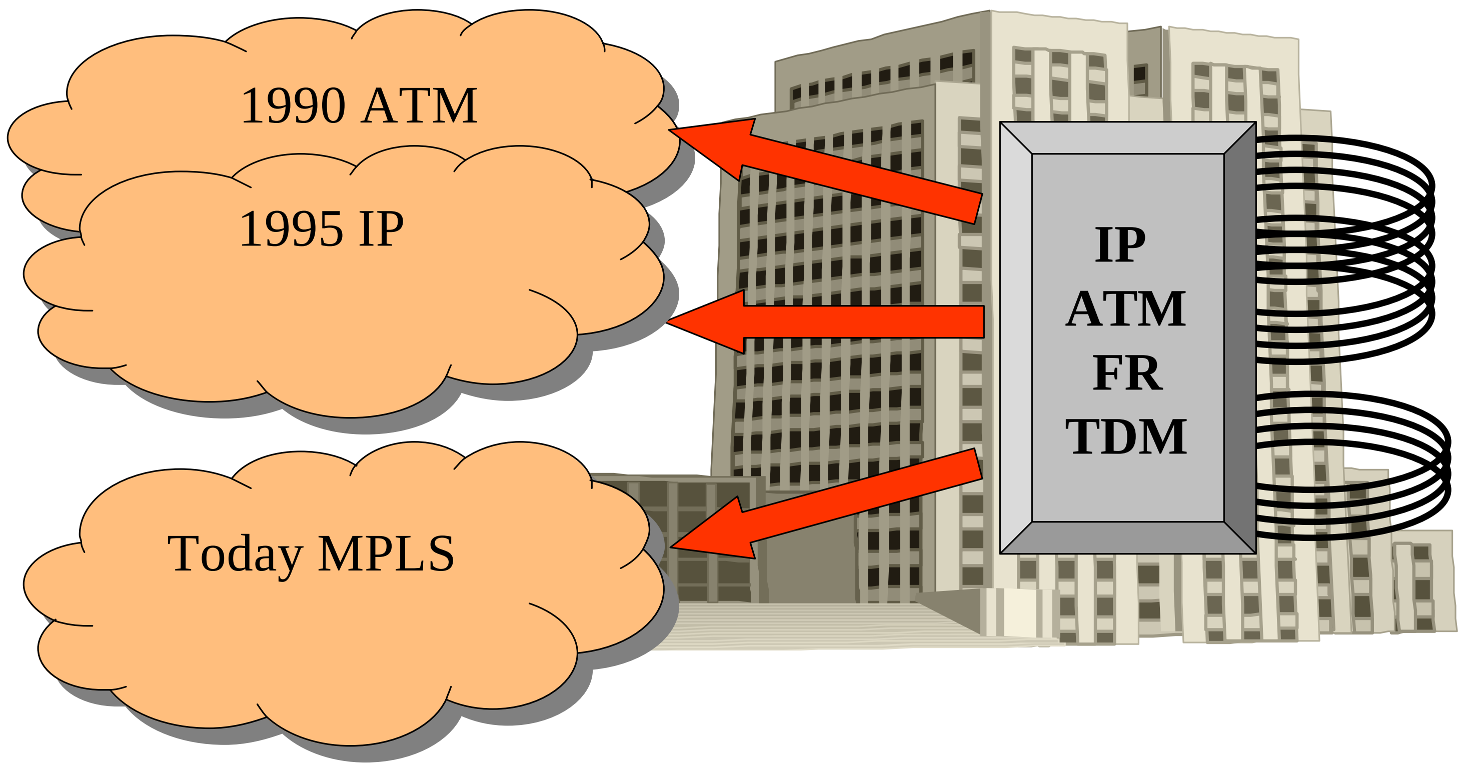
- Designed for voice and TDM services
- Based on resilient SONET/SDH transport (< 50msec protection)
- Carrier class reliability (99.999%)

The Long Haul Network



- IP network is connectionless best effort
- ATM network is connection oriented – it supports traffic engineering and QoS
- TDM network is statically provisioned, reliable, supports SLAs

The Promise of Convergence



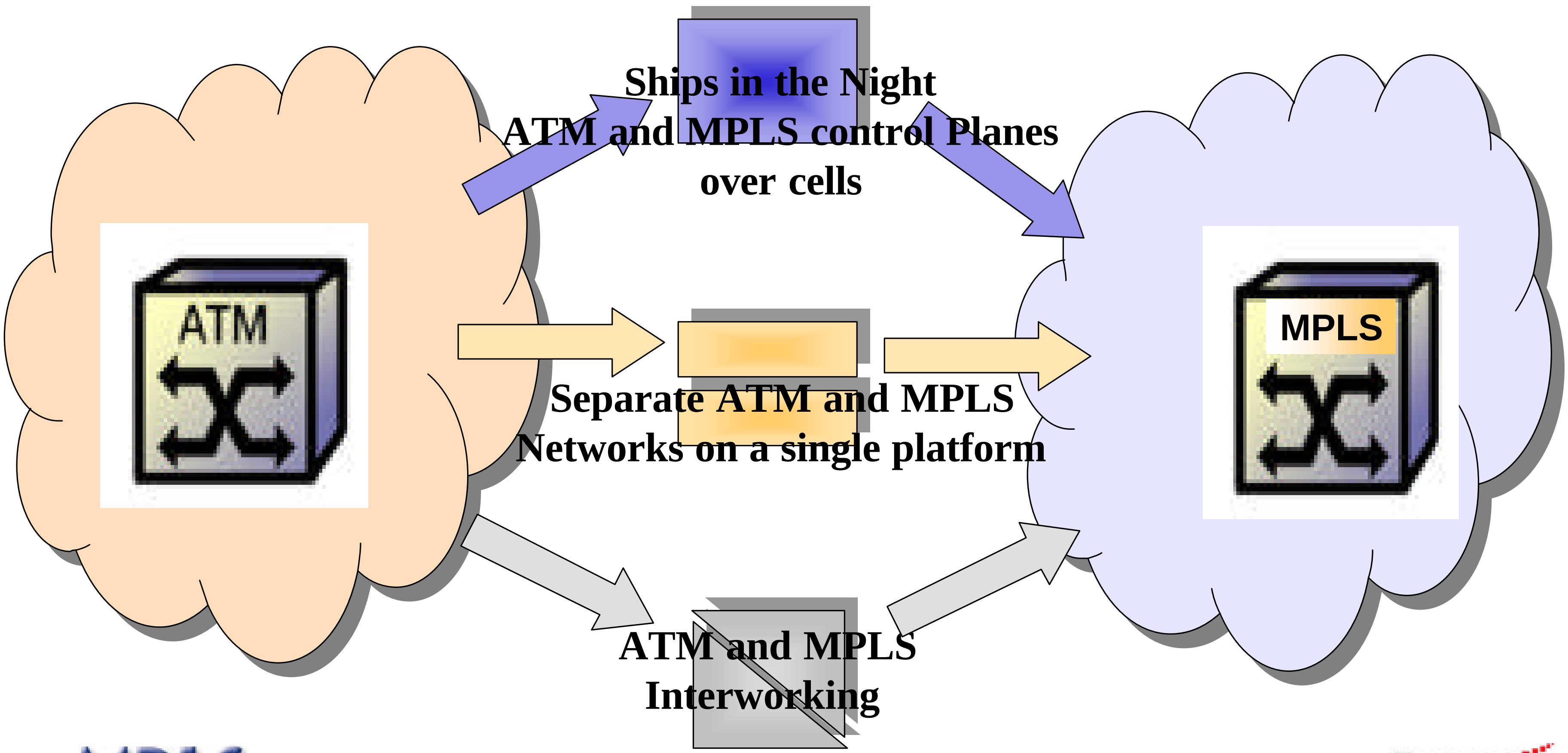
Challenges at the Edge

- **Transparently provide end-to-end support for existing Layer 1 and Layer 2 services**
  - ✓ ATM, Frame Relay, PPP, HDLC
- **Transparently provide support for Layer 3 services**
  - ✓ VPNs, Internet Connectivity
- **Enable new services**
  - ✓ Ethernet Services
    - Private Line
    - Virtual Private LAN Service (VPLS)
    - Hierarchical VPLS (HVPLS)
  - ✓ Inter-working

Why not ATM?

- ATM is optimized for voice transport
- MPLS is optimized for packet transport
- Cells are simply fixed length packets and can be carried unchanged across an MPLS network
- Packets are not cells and must be adapted to be carried across ATM
- MPLS offers operational efficiency

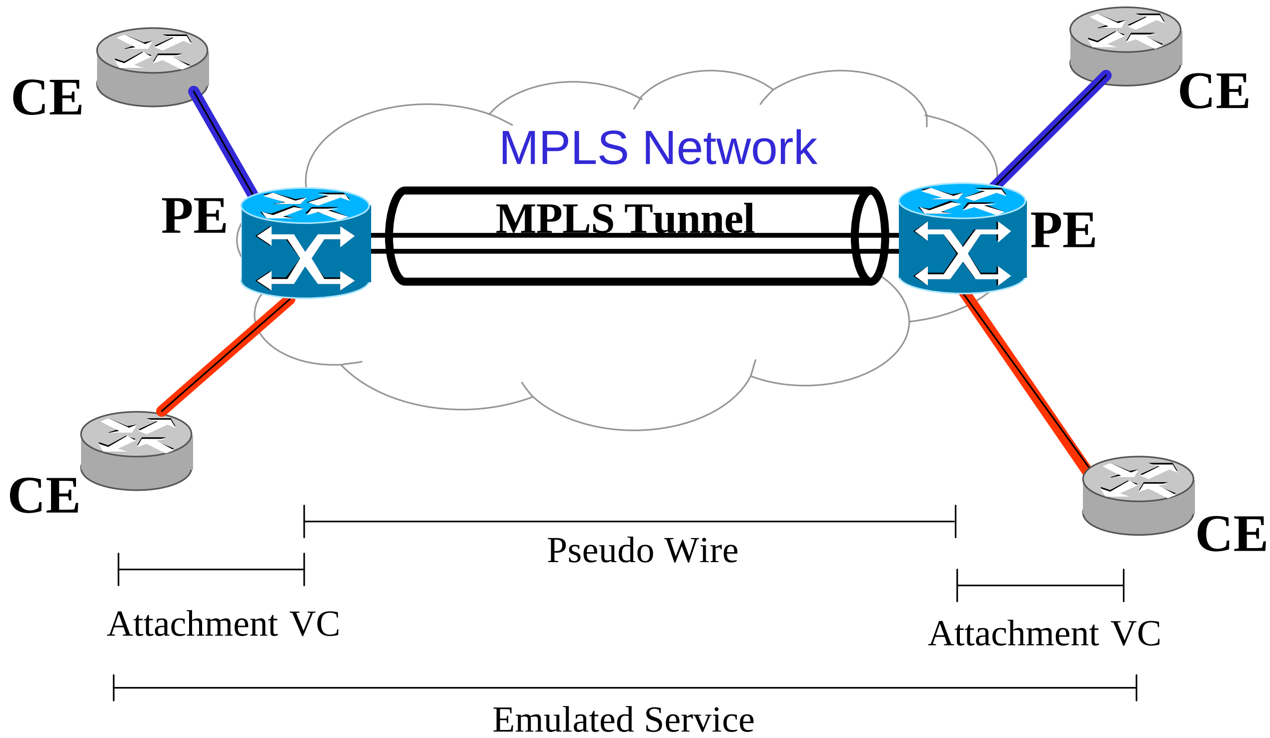
ATM to MPLS Approaches



ATM-MPLS Convergence Issues

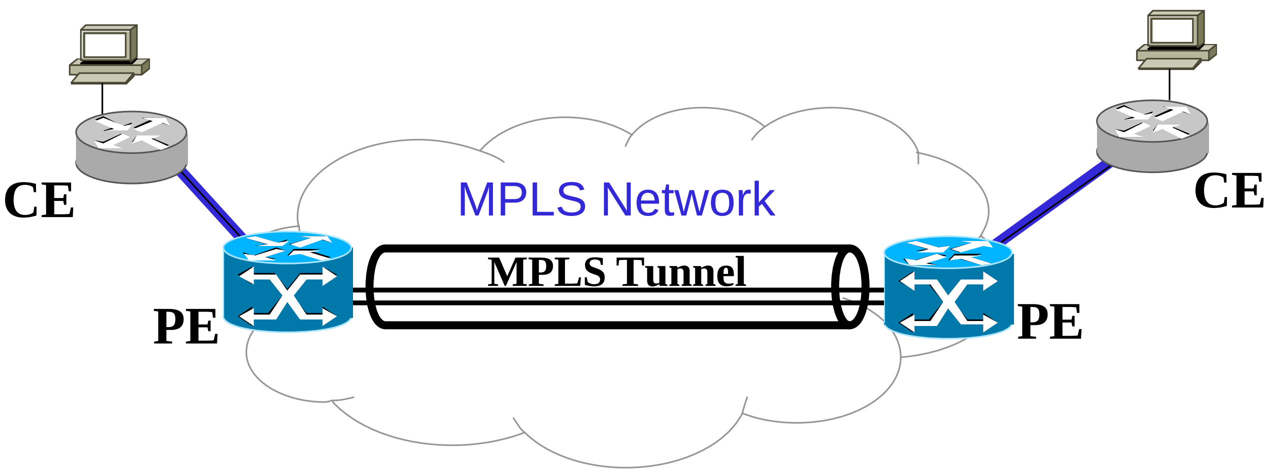
- Encapsulation
  - ✓ Cells in frames
  - ✓ Frames in frames
- Signaling
  - ✓ LDP based
  - ✓ PNNI Based
- Transparency and QoS
  - ✓ Ordering and timing
  - ✓ Classification, policing, scheduling, shaping
  - ✓ CAC and WFQ
- Management

PWE3 Reference Architecture



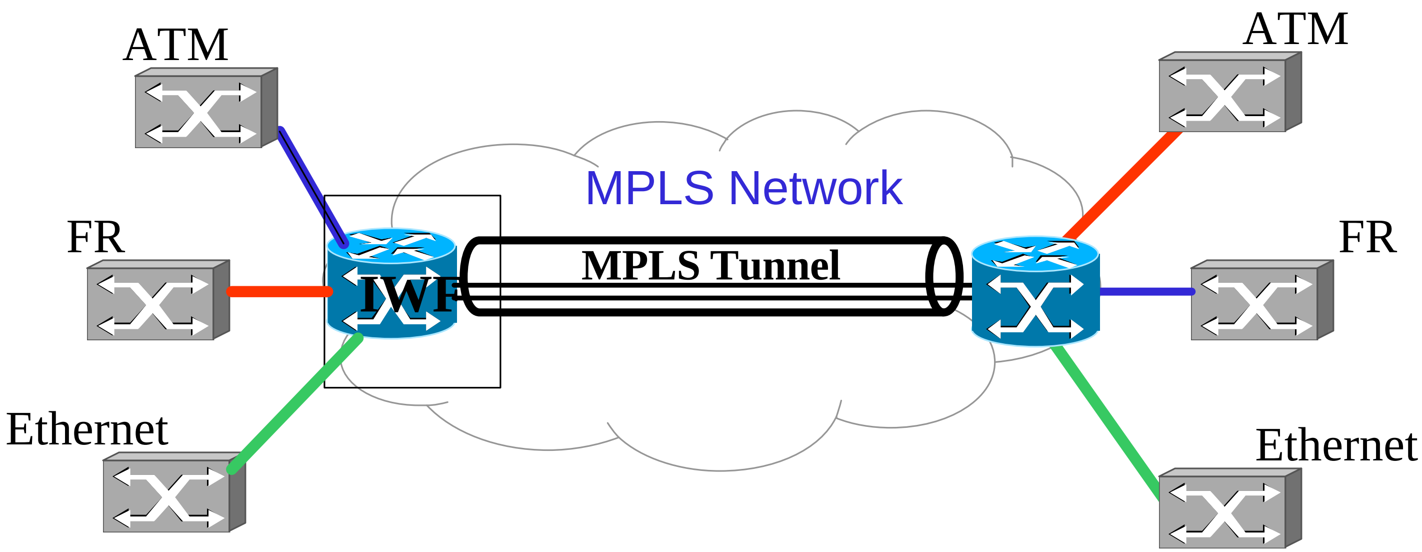
- Pseudo Wire Edge to Edge Emulation – Layer 2 over MPLS

VPWS Reference Architecture



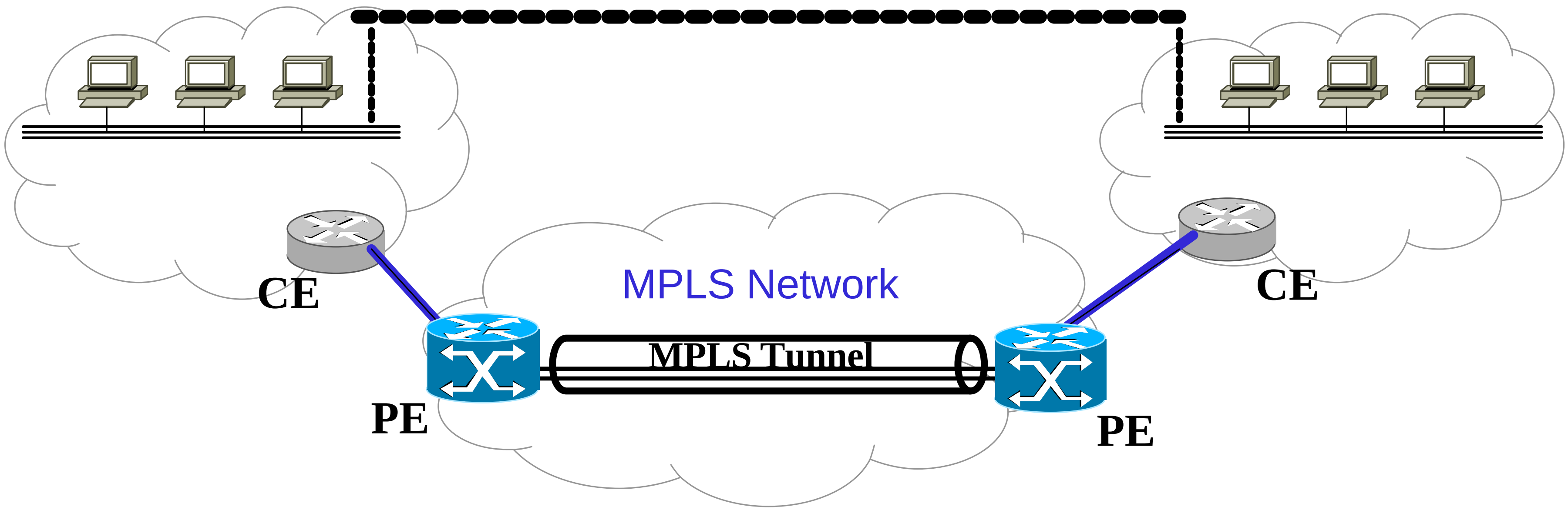
- Virtual Private Wire Service (VPWS)
- Provides a Point-Point service between CE sites

Layer 2 Interworking Architecture



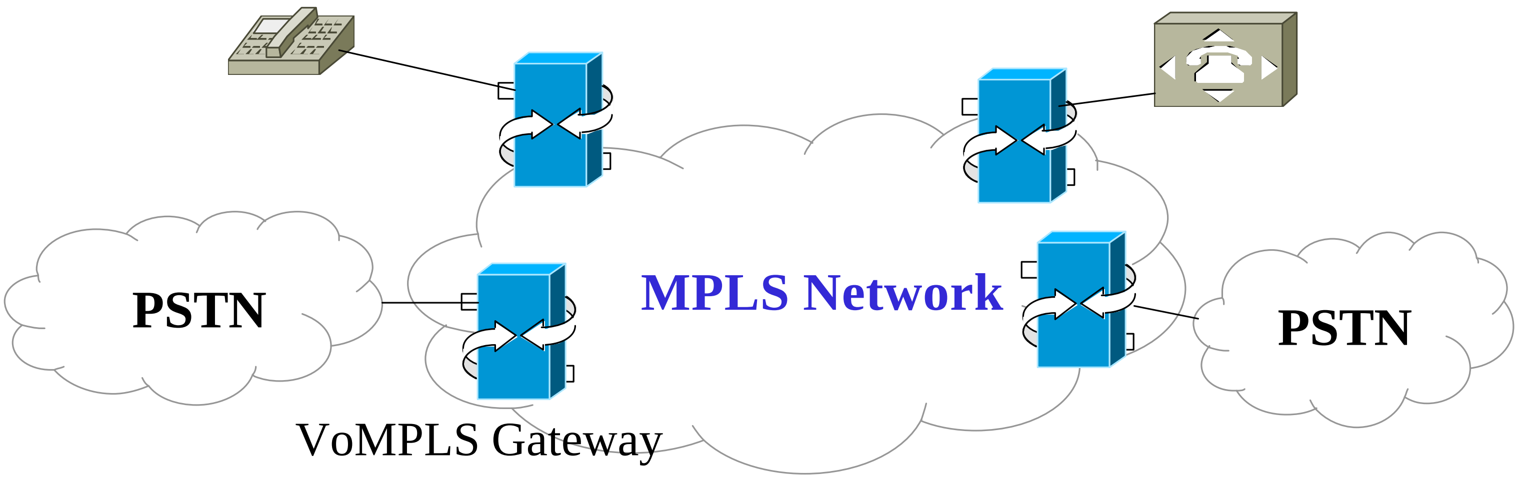
- Interworking function (IWF) translates Layer 2
  - ✓ Maps protocols
  - ✓ Maps QoS fields

VPLS Reference Architecture



- Virtual Private LAN Service (VPLS)
- Provides a multipoint bridge service among different CE sites

VoMPLS Reference Architecture



- Voice over MPLS (VoMPLS)
- Incoming voice protocol such as TDM voice from an ISDN or PSTN network is terminated at the MPLS network gateway
- Voice sample is mapped directly to MPLS frames at the MPLS network gateway

Why Migrate to MPLS?

- MPLS allows service providers to converge into a single infrastructure while offering the service they currently support
- MPLS enables new service offerings and simplifies service provisioning
- MPLS natively supports rapid growth in IP applications and services
- MPLS allows the integration of the emulated services management into common OSS strategy
- Positioned to support integration of packet technologies and optical core

Service Provider Challenges

- Provide a predictable service to customers
  - ✓ High Availability
  - ✓ High Quality of Service
  - ✓ High Versatility
- Offer new services
  - ✓ Tiered services
  - ✓ Guaranteed services
  - ✓ VPN services
- Maintain a scalable network

Service Provider Requirements

- Versatility
  - ✓ Minimize congestion via traffic engineered paths engineered paths
  - ✓ Traffic aggregation
- Service granularity
  - ✓ QoS enabled MPLS
  - ✓ Guaranteed service
    - Independent of switch congestion
- High Availability
  - ✓ Ability to dynamically recover from node or link failures node or link failures
    - Automatic re-route
    - Path restoration

It makes business sense

Minimize CAPEX	→	Leverage existing infrastructure New service introduction
Reduce OPEX	→	Network and services convergence Simplifies service provisioning Automates operation
Enables new services	→	Incremental revenue opportunities More focused ROI Embraces emerging technologies

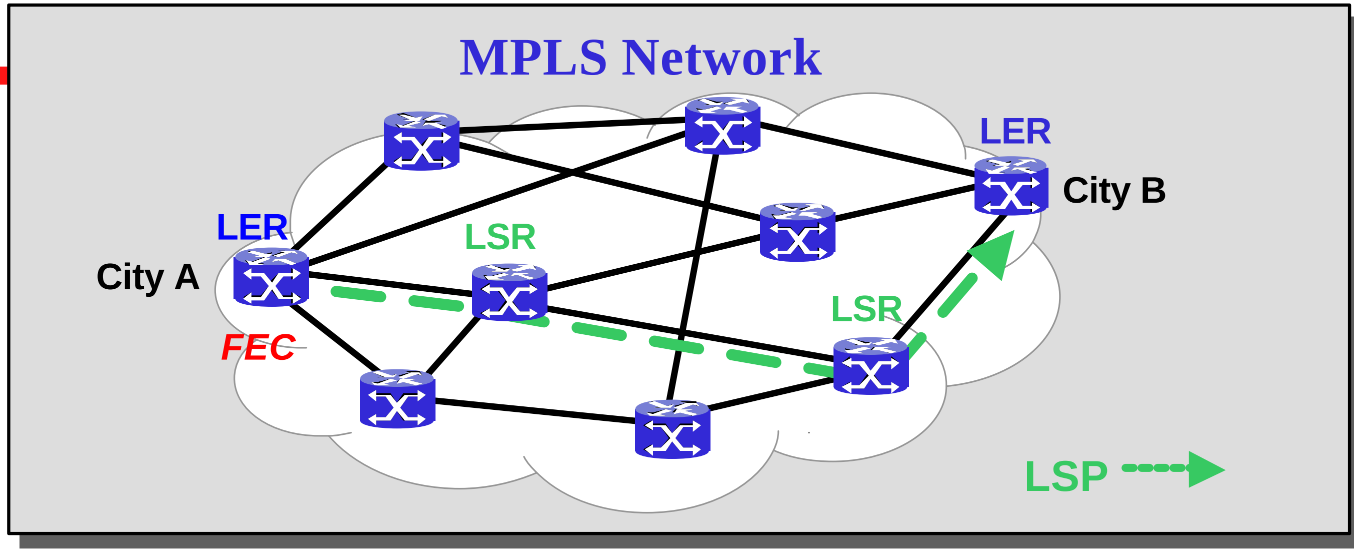
MPLS Overview

Section 3

Agenda

- MPLS Network Solution Overview
- Topology Determination
- Labels & Label Distribution
- Differentiated Services – Diffserv
- Dealing with Contention
- Network Resiliency
- LDP Extended Discovery
- MPLS PVC UNI
- References

MPLS Model



- Routers that handle MPLS and IP are called Label Switch Routers (LSRs)
- LSRs at the edge of MPLS networks are called Label Edge Routers (LERs)
- Ingress LERs classify unlabelled IP packets and appends the appropriate label.
- Egress LERs remove the label and forward the unlabelled IP packet towards its destination.
- Traffic is grouped into subsets. All packets in a subset (Forwarding Equivalence Class (FEC)) are forwarded along the same path through the MPLS network.

Components: Control Plane and Forwarding Plane

- Control Plane create LSP
  - ✓ Controls characteristics by manipulating label bindings
    - Traffic Engineering
    - Differentiated Services
    - VPNs
- Forwarding Plane
  - ✓ Efficient lookup and forwarding
  - ✓ Per-label forwarding, queuing etc
- Separation allows flexibility

Forwarding Equivalency Class

- Stream/flow of IP packets:
  - ✓ Forwarded over the same path
    - Traffic can be spread over multiple paths with Equal Cost Multipath (ECMP) routing
  - ✓ Mapped to the same label
  - ✓ Multiple FEC's may be mapped to the same FEC
  - ✓ Different LSP may be used to provide QoS
  - ✓ For QoS may use the Exp bits for mapping
- FEC/label binding mechanism
  - ✓ Binding is done once at the ingress
  - ✓ Usually based on destination IP address prefix
  - ✓ May be port switched

MPLS Technology

There are three key elements of MPLS

- ✓ The **MPLS header stack**
  - Which contain the MPLS label on which Label Switch Routers will forward the packet. Headers can be stacked.
- ✓ The **enhanced IP routing protocols**
  - Which distribute topology and constraint based data
- ✓ The **label distribution protocols**
  - The standardized connection establishment protocols through which LSR's set up a complete path from ingress LSR to egress LSR.

MPLS adds a connection-oriented paradigm into IP networks

MPLS Architecture

- Traffic Engineering
  - ✓ LSPs can be engineered to meet latency and loss objectives
- Resource reservation for traffic engineered paths
  - ✓ Resources can be reserved on a per-LSP basis
- Differentiated forwarding behaviors
  - ✓ Forwarding and drop behaviors can be controlled at the LSP level using E-LSPs and L-LSPs
- Path availability
  - ✓ At data forwarding level, redirect user traffic on the fly
- Graceful Restart
  - ✓ At control plane, recover the control information on the "down" nodes without disturbing data traffic

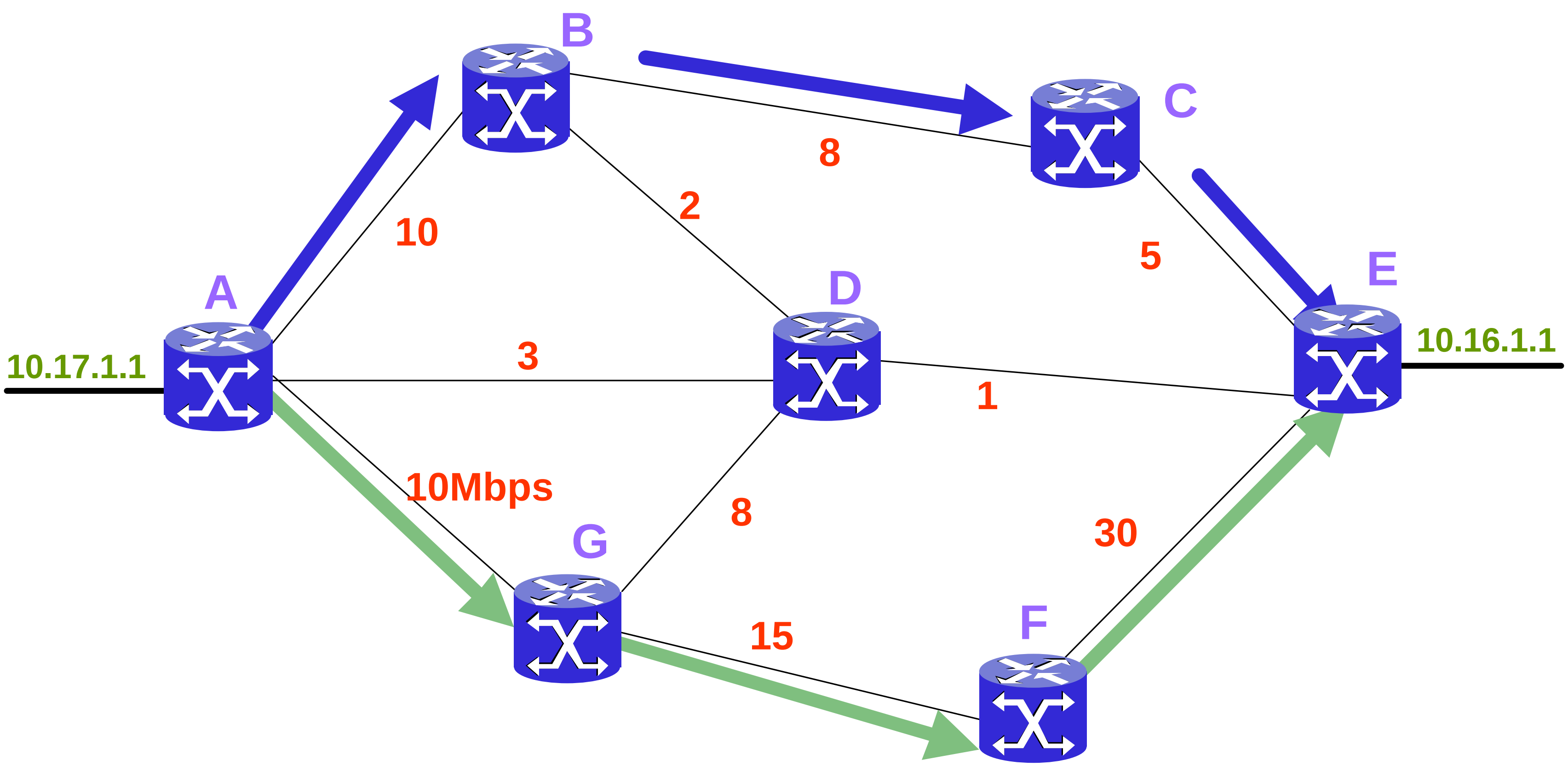
LSP Creation

- Label Distribution Protocol (LDP)
  - ✓ Each LSR independently selects the next hop for a given FEC
  - ✓ LSR uses any available routing protocols, such as OSPF, IS-IS
- Resource Reservation Protocol – TE (RSVP-TE)
  - ✓ Use to set-up a path with QoS guarantees
  - ✓ Utilize for traffic engineering
    - Explicit Routing — similar to source routing
    - Ingress LSR specifies the list of nodes through which the LSP traverses based on *constraints*
    - LSRs runs TE enabled link state routing protocols, such as OSPF TE, IS-IS TE
    - Resources may be reserved along the path to ensure QoS

Topology Determination

- Link-state routing protocols that advertise *more* than reachability
- The Link-State protocol must also advertise the *available link bandwidth*
- Two predominant protocols:
  - ✓ IS-IS with Traffic Extension (IS-IS TE)
  - ✓ OSPF with Traffic Extensions (OSPF TE)

Traffic Engineered LSP



Create a path requiring 6Mbps from 10.17.1.1 to 10.16.1.1 **(A,G,F,E)**

Create a path requiring 5Mbps from 10.17.1.1 to 10.16.1.1 **(A,B,C,E)**

Differentiated Services - DiffServ

- DiffServ model divides traffic into a small number of classes and pre-allocates resources on a per-class basis
- A packet's class is marked directly in the packet via the 6-bit Differentiated Service Code Point – DSCP
- DSCP identifies a "per hop behavior" or PHB
- The standard PHBs are:
  - ✓ Expedited Forwarding (EF) – minimal delay and low loss
  - ✓ Assured Forwarding (AF) – supports different classes and drop precedences
  - ✓ Best Effort (BE) – no special treatment

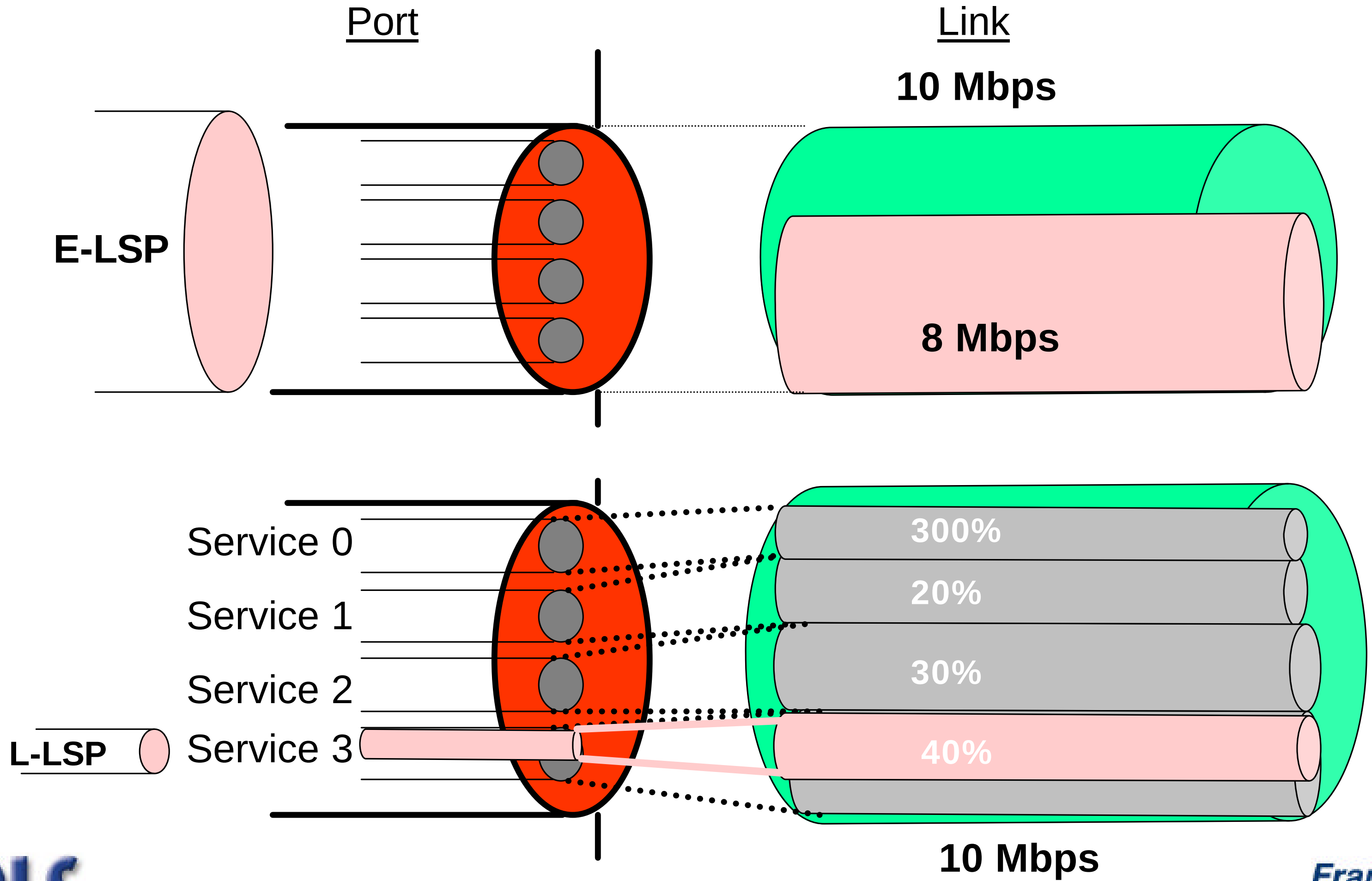
MPLS and DiffServ

- The DSCP value can then be represented in an MPLS Header value
- Scheme to determine the PHB from the MPLS Header value depends on the type of LSP – E-LSP or L-LSP
- MPLS and DiffServ can work in concert to provide CoS/QoS in a traffic engineered IP network

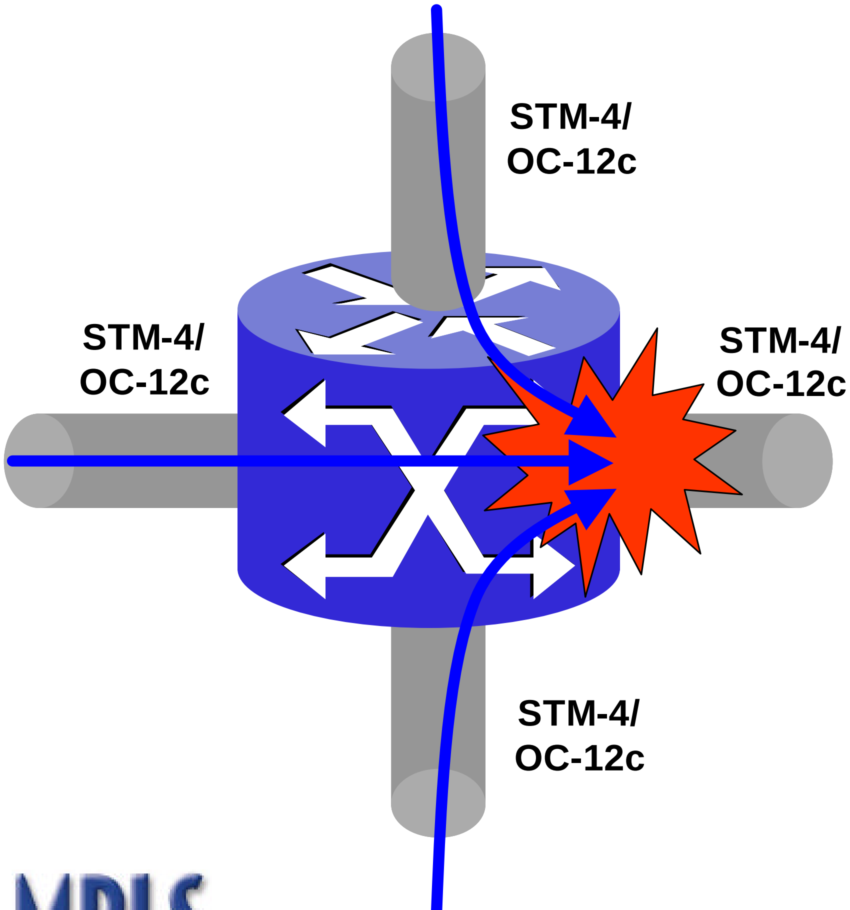
L-LSP and E-LSP

- Label-inferred LSP (L-LSP)
  - ✓ A separate L-LSP supports each Behavior Aggregate
  - ✓ Bandwidth allocated from specific PSC (Queue)
  - ✓ Label maps L-LSP using DSCP
  - ✓ EXP carries drop-precedence
- EXP-inferred LSP (E-LSP)
  - ✓ A single LSP may support up to eight Behavior Aggregates
  - ✓ Bandwidth allocated from the link bandwidth
  - ✓ EXP carries PSC (and perhaps drop-precedence)

E-LSP vs L-LSP


Port
Link
10 Mbps
E-LSP
8 Mbps
Service 0
Service 1
Service 2
L-LSP
Service 3
300%
20%
30%
40%
10 Mbps

LSR Characteristics



- Dealing with Contention
  - ✓ CAC
  - ✓ Policing
  - ✓ Marking
  - ✓ Buffering
  - ✓ Queuing
  - ✓ Scheduling
  - ✓ Shaping
  - ✓ Discard Policy

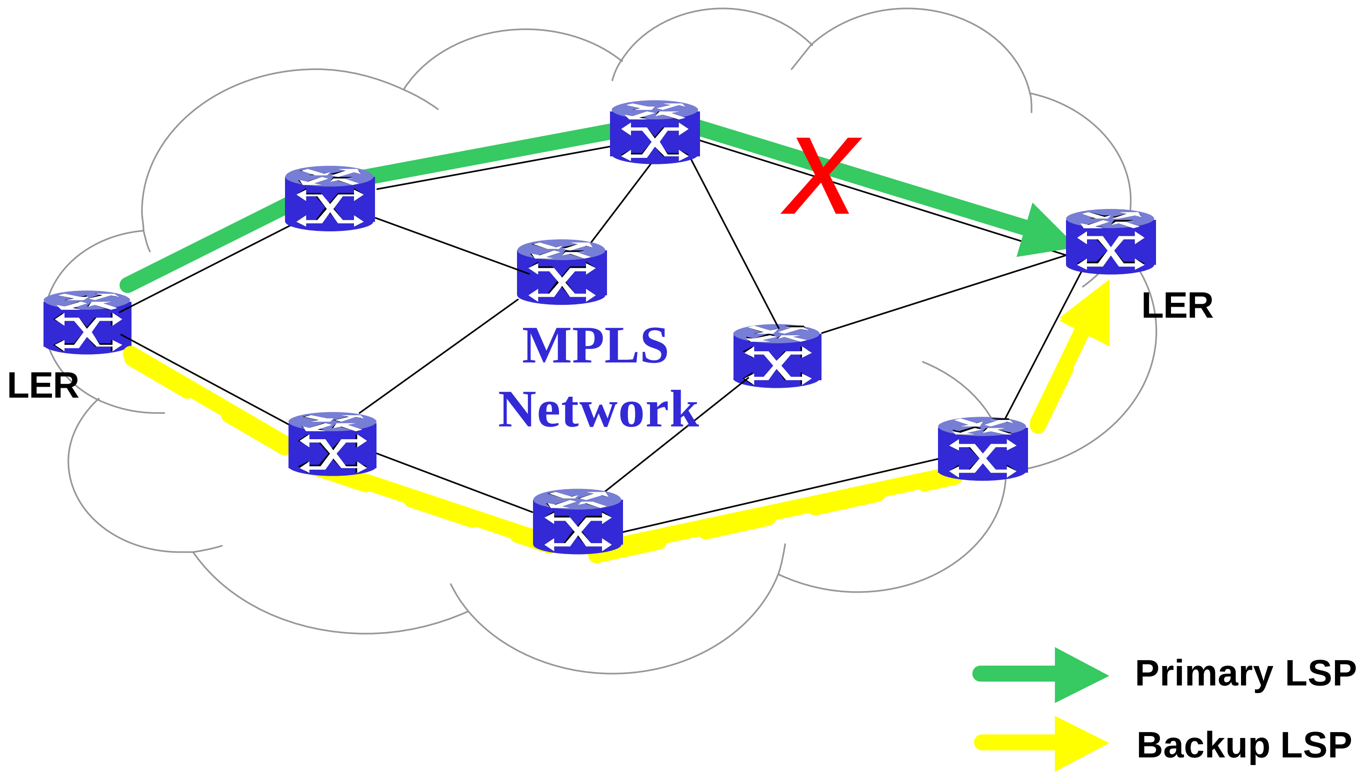
Providing Resiliency with MPLS

- Optical Layer
  - ✓ Partial or full mesh of optical switching systems
- Physical Layer
  - ✓ Automatic Protection Switching strategies of SONET/SDH
- MPLS Layer
  - ✓ Outage
    - Protection and Re-routing procedures
  - ✓ Administrative
    - Re-optimization and Preemption
- IP Layer
  - ✓ IGP convergence algorithms

LSP Recovery Mechanisms

- **Re-Routing**
  - ✓ Recovery mechanism in which the LSPs are created dynamically
- **Protection Switching**
  - ✓ Recovery mechanism in which the LSPs are created prior to detection of a fault
- **Recovery Path**
  - ✓ Path (LSP) by which traffic is restored after the occurrence of a fault
- **Topology**
  - ✓ Local Repair
    - To protect a single link or neighbor node fault
  - ✓ Global Repair
    - To protect against any link or node failure along an LSP

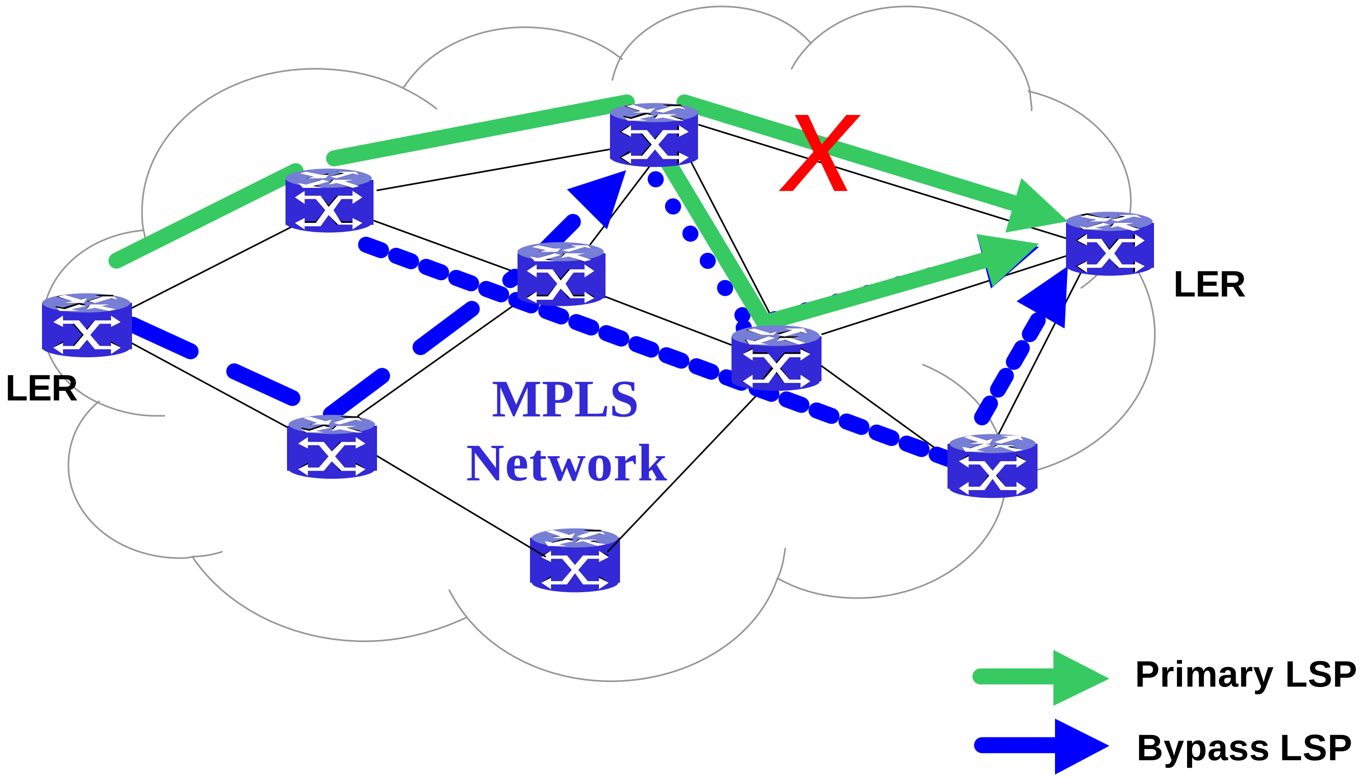
Backup LSP



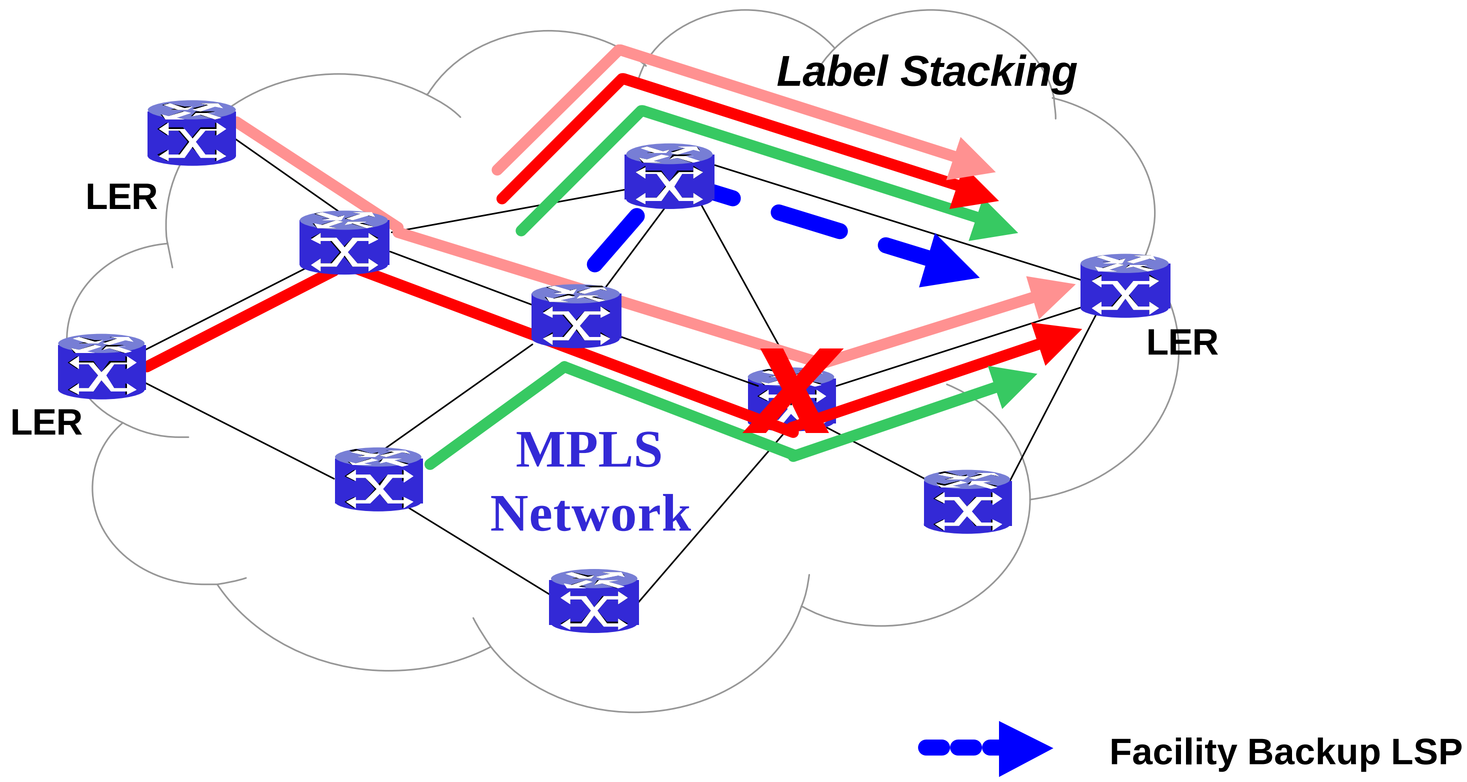
Fast Reroute

- Two methods for backup tunnels exist.
  - ✓ One-to-One backup creates individual detour LSPs at each PLR (Point of Local Repair) for each primary LSP. Detour LSPs can merge together to improve scalability.
  - ✓ Facility backup associates one or more bypass tunnels with a given resource (link or node). Each primary LSP which uses PLR, resource, and merge node in order can use associated bypass tunnel. Takes advantage of MPLS label stacking
- Ingress requests local-protection and the type of backup desired for primary LSP.
- New RSVP-TE Objects include:
  - ✓ FAST_REROUTE
  - ✓ DETOUR

One-to-one Backup



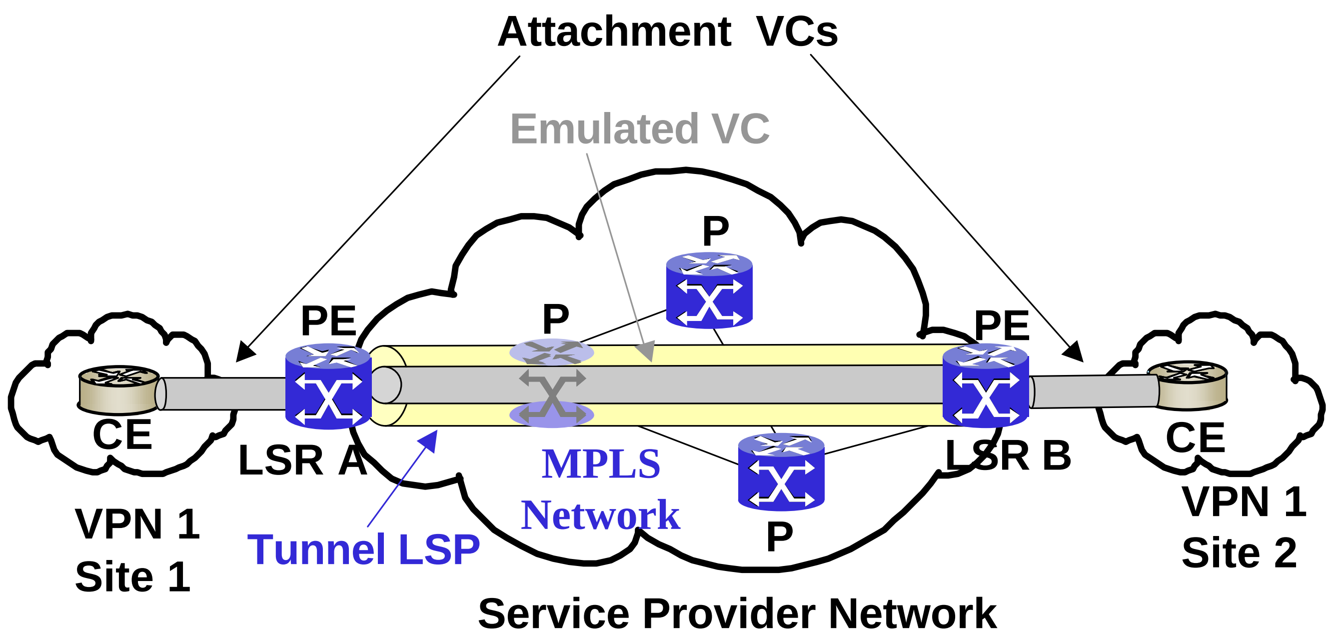
Facility Backup



Resiliency - Protocol Graceful Restart Capabilities

- **Motivation:** Make control plane faults “self healing”
- **Key Ideas:**
  - ✓ Do not let control plane failure affect a healthy forwarding plane
  - ✓ Neighboring nodes pre-negotiate restart capabilities & parameters
  - ✓ A node whose control plane fails, but whose forwarding plane is active continues forwarding while preserving protocol state across the failure
  - ✓ Neighbors preserve adjacencies with a recovering peer
  - ✓ When control plane at that peer is “up”, neighbors coordinate to restore/update state on that peer
  - ✓ Capability supported on OSPF-TE, RSVP-TE and LDP
- Enables service providers to preserve the high availability FR/ATM service solutions with SLAs with MPLS

MPLS Enabled Layer 2 VPNs



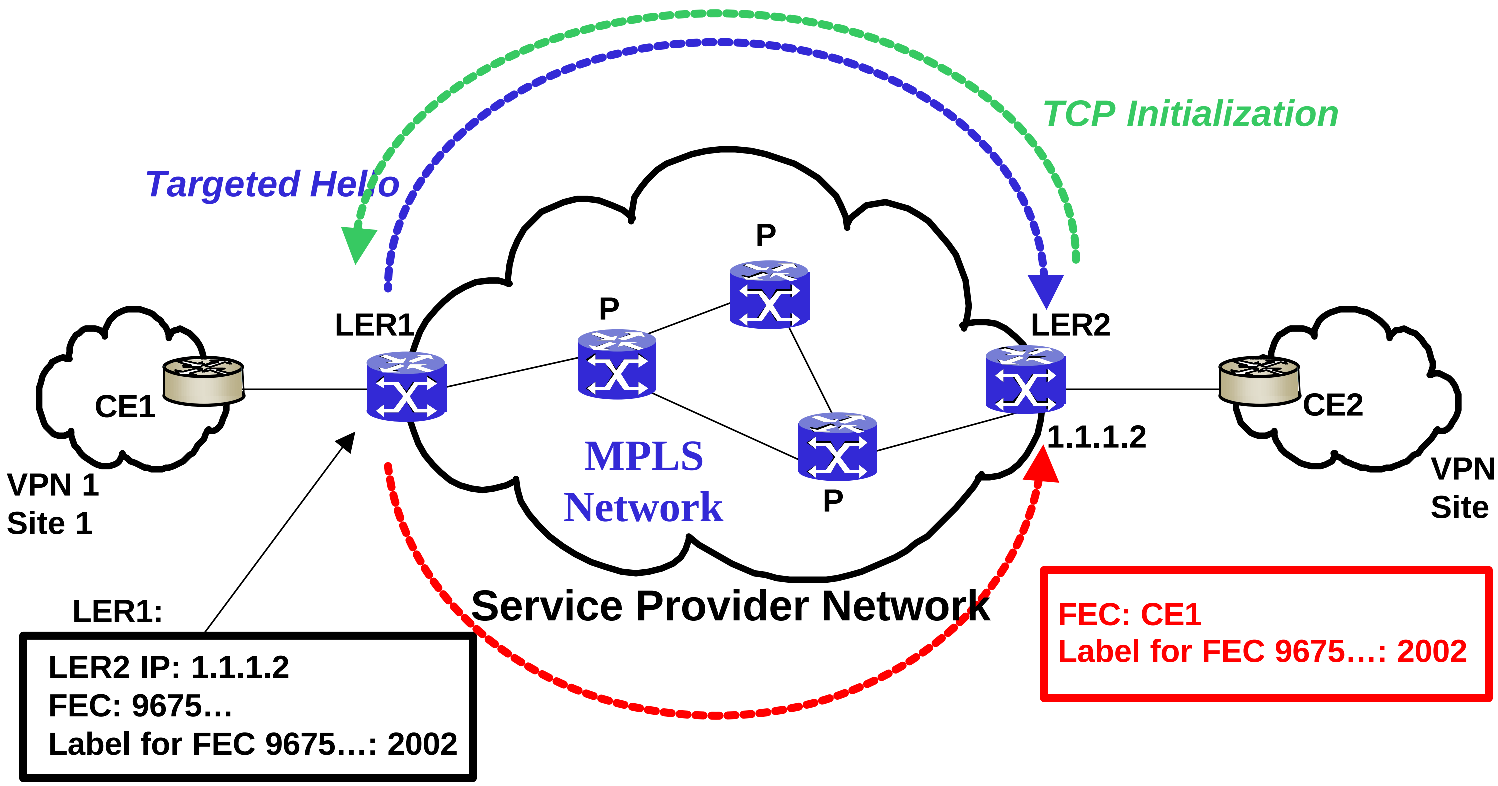
There are two proposed mechanism for associating the 'Attachment VC'

- LDP Extended Discovery
- BGP NLRI Label Block

LDP Extended Discovery

- Enables LSRs that are not directly connected to engage in LDP label distribution (*targeted session)*
- LDP Extended Discovery which uses *Targeted Hello* messages sent to specific IP addresses.
- Unlike Basic Discovery, which is symmetric, Extended Discovery is asymmetric. Targeted LSR decides whether to respond to or ignore the Targeted Hello.

LDP Extended Discovery with a Layer 2 VPN Solution



MPLS PVC UNI

- Provisioned PVC LSP service for transport of MPLS traffic over a public MPLS network
- Supports variable length packets over PPP, POS, Ethernet, FR or ATM L2 encapsulation
- Service defined with:
  - ✓ Bandwidth parameter
  - ✓ Identification attributes
    - MPLS label significant to the PVC UNI
    - LSP identifier that uniquely identifies LSP within the public network
  - ✓ Bi-directional LSP binding attributes
- Provides CPE with information including status and attributes of associated LSPs

MPLS & Frame Relay Alliance "MPLS PVC User to Network Interface Implementation Agreement" (MPLS/FR.2.0.1, May 2003)

Reference Material

- Multiprotocol Label Switching Architecture (RFC 3031)
- MPLS Label Stack Encoding (RFC 3032)
- Use of Label Switching on Frame Relay Networks Specification (RFC 3034)
- ATM – MPLS mediation: btd-aic-mpls-niwf-02.03 "ATM-MPLS Interworking: Network Interworking v2.0"
- FR - MPLS mediation: mplsforum2002.085.00 "Frame Relay and MPLS Network Interworking IA – Baseline Text"
- LDP Specification: RFC 3036
- Graceful Restart Mechanism for LDP (RFC 3478)
- L2 VPNs:
  - VPLS-BGP: draft-ietf-l2vpn-vpls-bgp-00
  - VPLS-LDP: draft-ietf-l2vpn-vpls-ldp-00
- Fast Reroute: Draft-ietf-mpls-rsvp-lsp-fastreroute-03.txt "Fast Reroute Extensions to RSVP-TE for LSP Tunnels"
- MPLS PVC UNI: MPLS & Frame Relay Alliance "MPLS PVC User to Network Interface Implementation Agreement" (MPLS/FR.2.0.1, May 2003)

End of
Section 3

Thank You

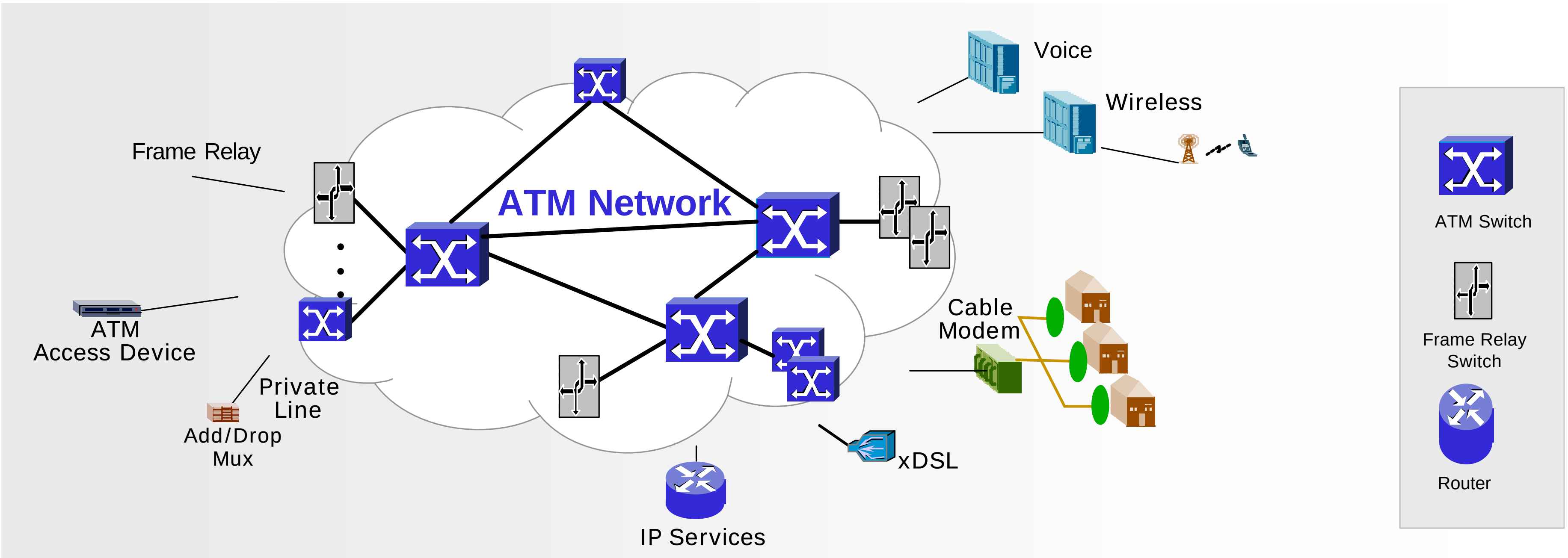
Migrating Frame Relay and ATM to MPLS

Section 4

Section 4: Agenda

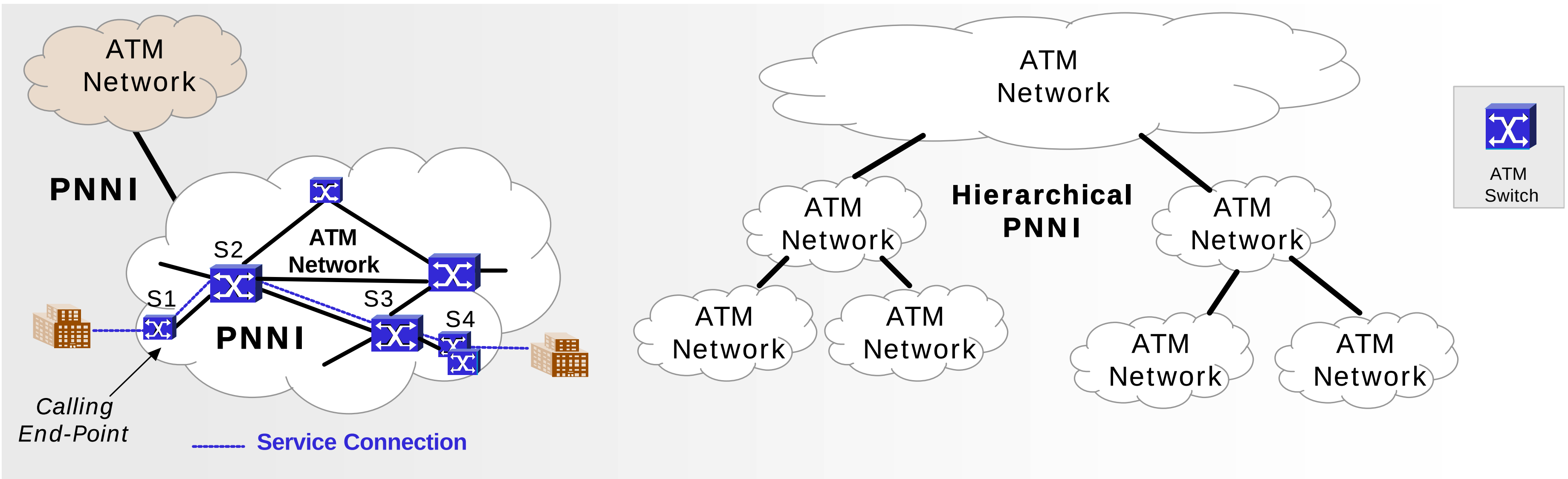
- Current ATM and Frame Relay Solutions & Terminology
- Integration Strategies: Motivations and Solutions
- How Does a ATM - MPLS Solution Work?
  - ✓ Data Plane
  - ✓ Control Plane
  - ✓ Solution Scalability
  - ✓ Resiliency
  - ✓ Management Plane
- How Does a Frame Relay – MPLS Solution Work?
- Summary

Current ATM/FR Network



- Typically frame relay (FR) & ATM on edge with ATM backbone
  - Network and service interworking (FRF.5 and FRF.8.1)
- Multiservice network support broad range of services & applications
- Virtual Connections & Paths: permanent, soft permanent and switched

Current ATM Backbone Networks



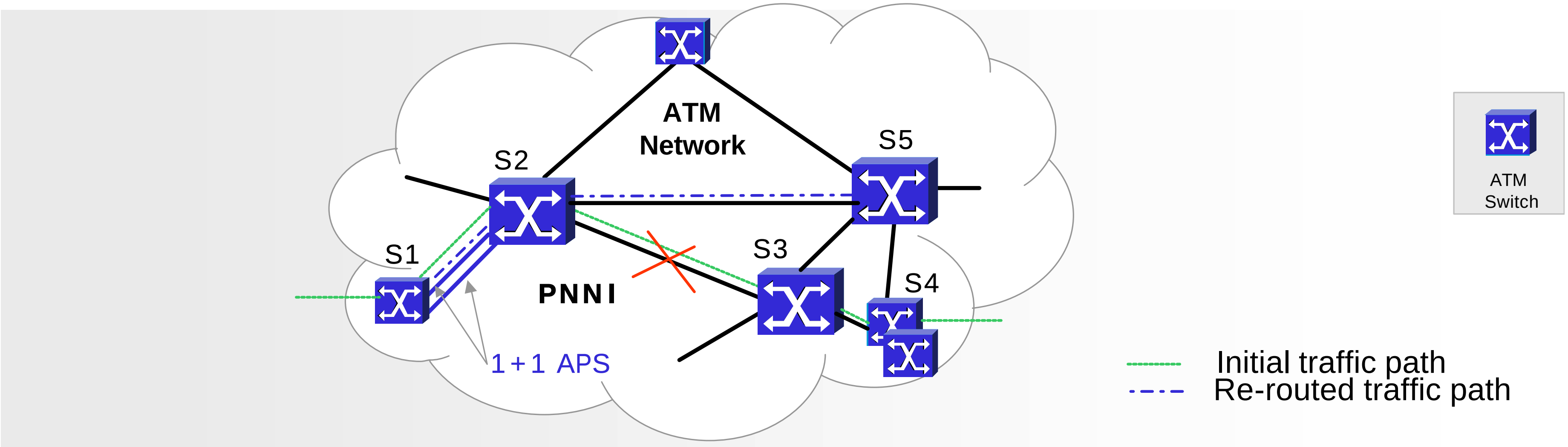
- Private Network-Network Interface (PNNI)
  - ✓ Protocols for distributing topology information and signaling pt-pt and multi-point connections across ATM network
- Simplified service provisioning with soft/switched connections & paths
  (Soft PVCC, SPVC, Soft PVPC, SPVPC) - provision connections at edges of network
- Hierarchical PNNI (HPNNI) network architecture for scalability

Key Frame Relay/ATM Attributes to be Preserved

- From an end-user's perspective
  - ✓ Low cost of ownership – multiple applications can share a single circuit (statistical muxing)
  - ✓ Dynamic bandwidth allocation capabilities
  - ✓ Performance, QoS, and reliability - Service Level Agreements (SLAs)

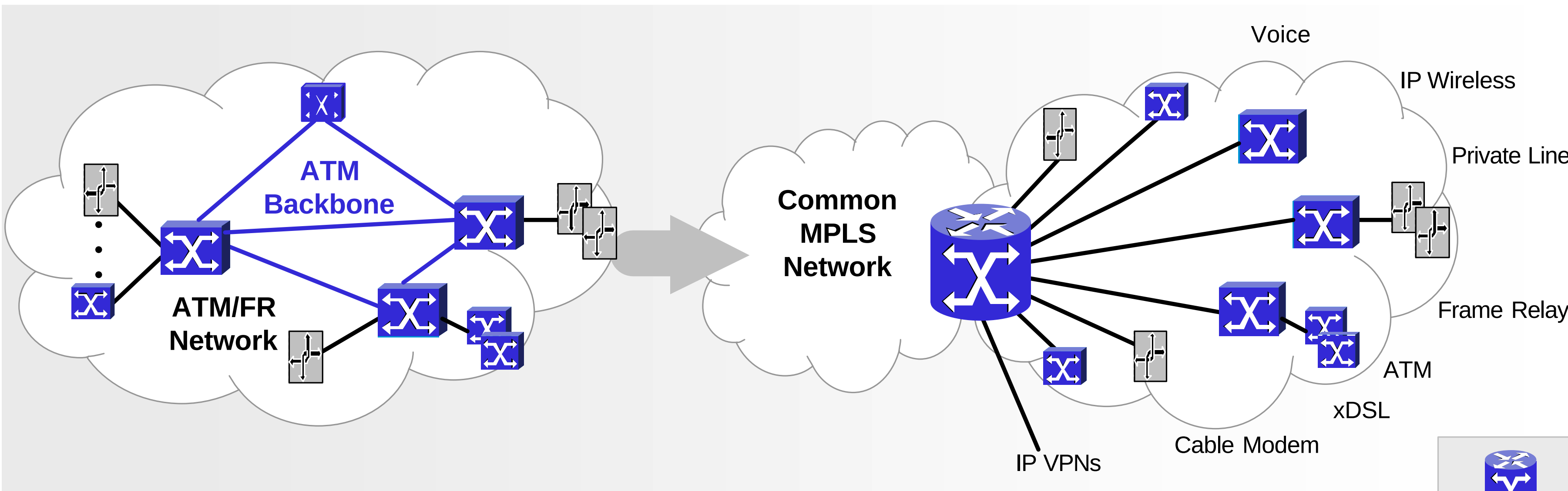
- From a service provider's perspective
  - ✓ Large established & growing profitable services
  - ✓ Frame Relay/ATM interworking
  - ✓ ATM network flexibility, scalability, reliability and QoS
  - ✓ Comprehensive management

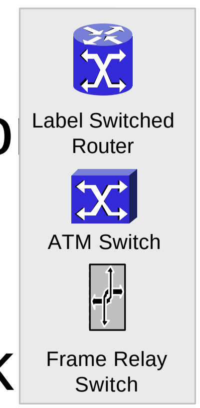
Current ATM Backbone Networks



- High availability: Restoration with domain-based re-routing on PNNI network and 50 millisecond 1+1 Automatic Protection Switching (APS) (GR-253)
- Management supported with OAM standards and tools that have evolved over several years for connection oriented services
  - ✓ Loop backs, F4/F5 flows, AIS-RDI, …

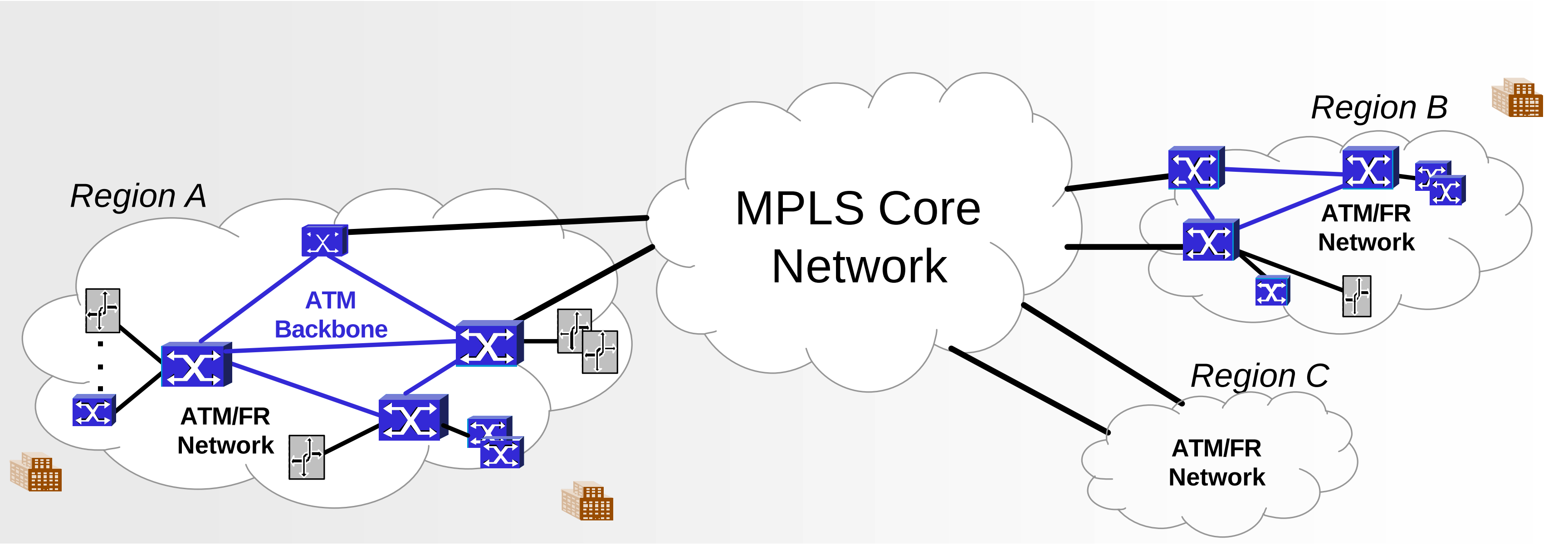
Motivations for Adding MPLS





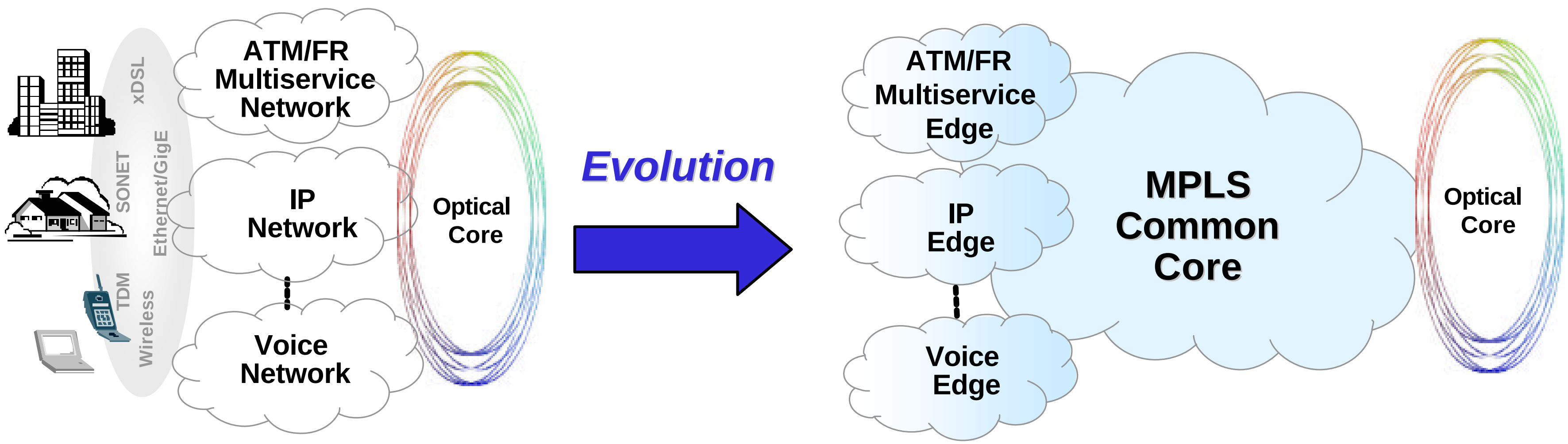
- Scale ATM/FR network aggregation and connectio capacity to support traffic growth
  - ✓ Free-up I/O slots on existing switches for services
- Add new IP VPN services on a converged network

Motivations for Adding MPLS



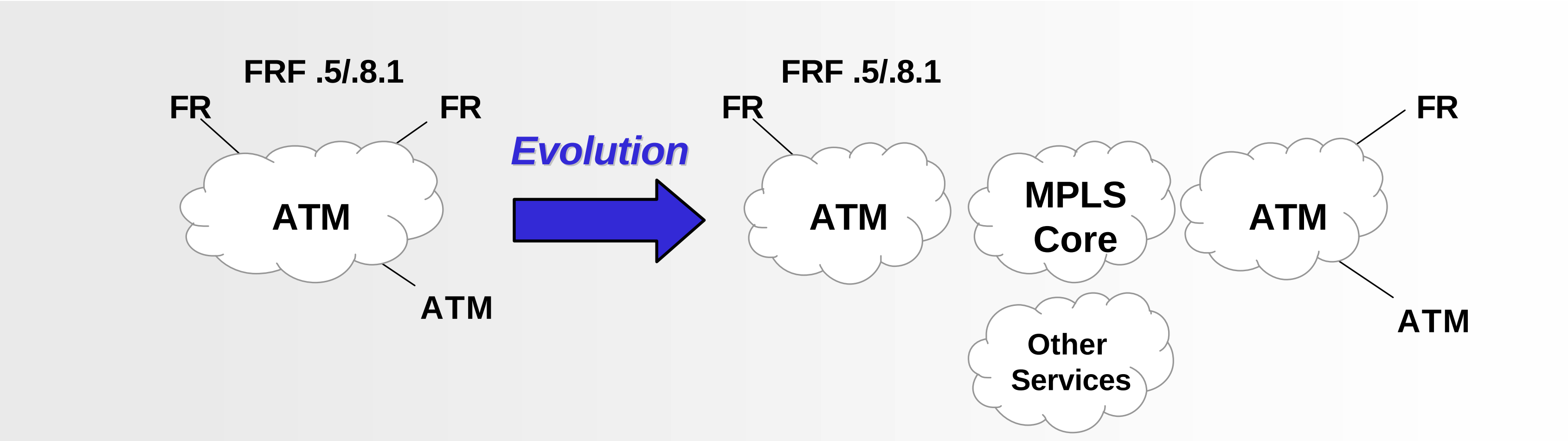
- Expand service offering reach by combining multiple ATM/FR networks
- Common MPLS core for all services

Motivations for Adding MPLS



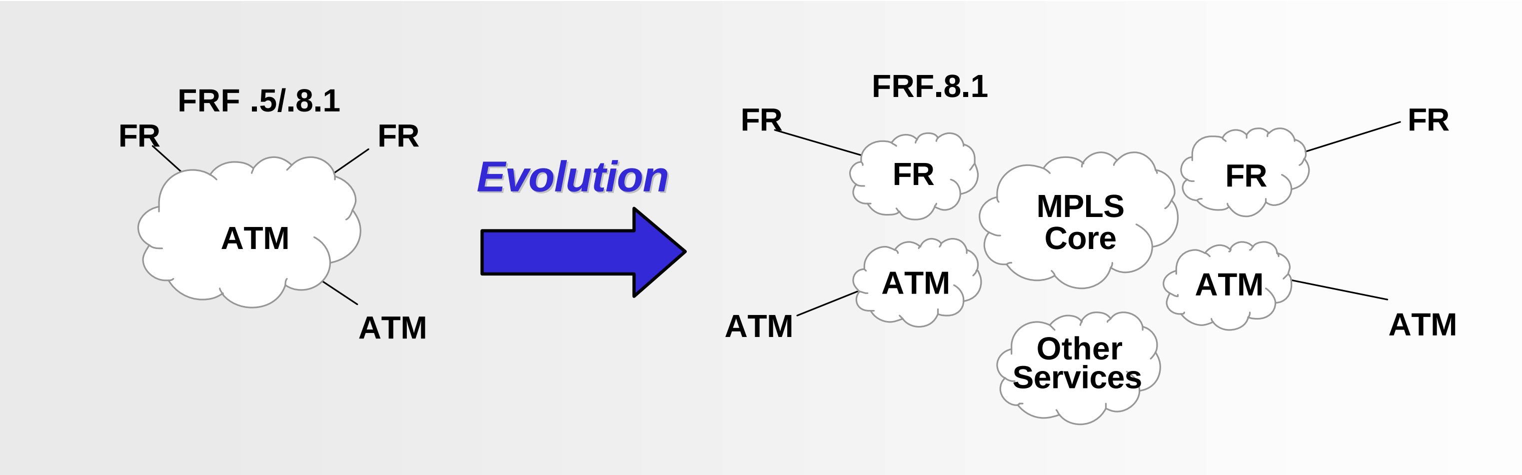
- Service specific network convergence to reduce risk with changing service mix
- New hybrid services
- CAPEX and OPEX savings

Key Migration Alternatives



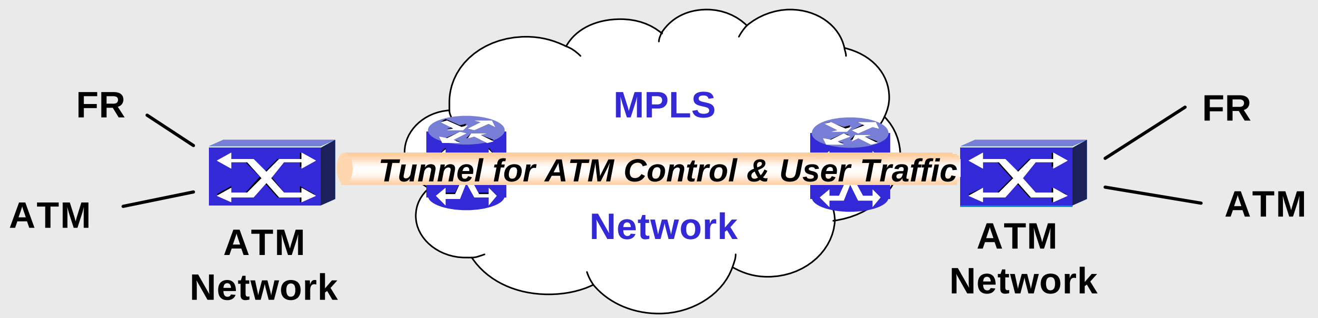
- ATM network currently supports ATM & FR services (FRF.5/.8.1)
- Migrate to MPLS core
  - ✓ Minimize impact on existing services and operations
  - ✓ Reduce FR efficiency (FR → ATM → MPLS → ATM → FR/ATM)
  - ✓ MPLS complexity stays at the Core
  - ✓ Adds to complexity of network management

Key Migration Alternatives



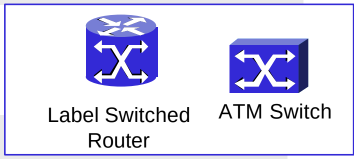
- ATM network currently supports ATM & FR services (FRF.5/.8.1)
- Migrate FR separately from ATM to MPLS core (no FRF.5)
  - ✓ Maximize FR transport efficiency
  - ✓ Minimize FR overhead (FR → MPLS → FR and ATM → MPLS → ATM)
  - ✓ Replace ATM traffic engineering and restoration with MPLS
  - ✓ Requires change to existing FR traffic in most networks (OPEX conversion cost)

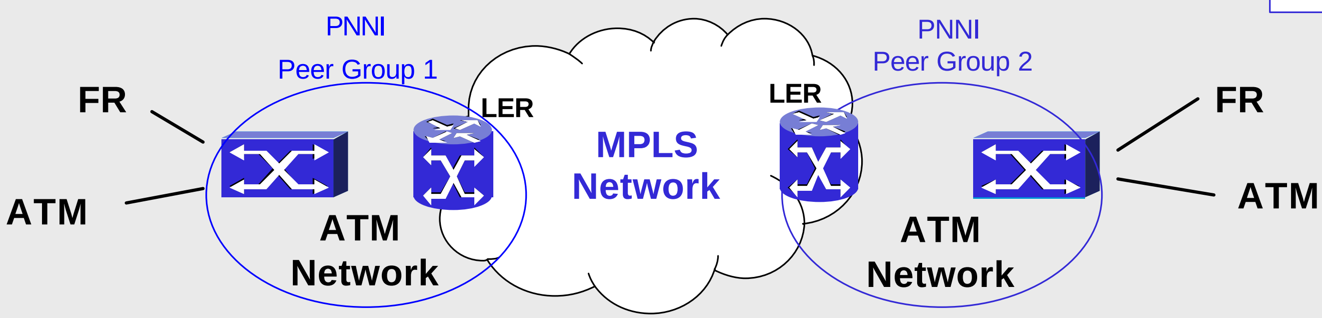
Key ATM - MPLS Migration Alternatives



- MPLS network appears as a tunnel to the ATM network for traffic transport – Overlay model

OR



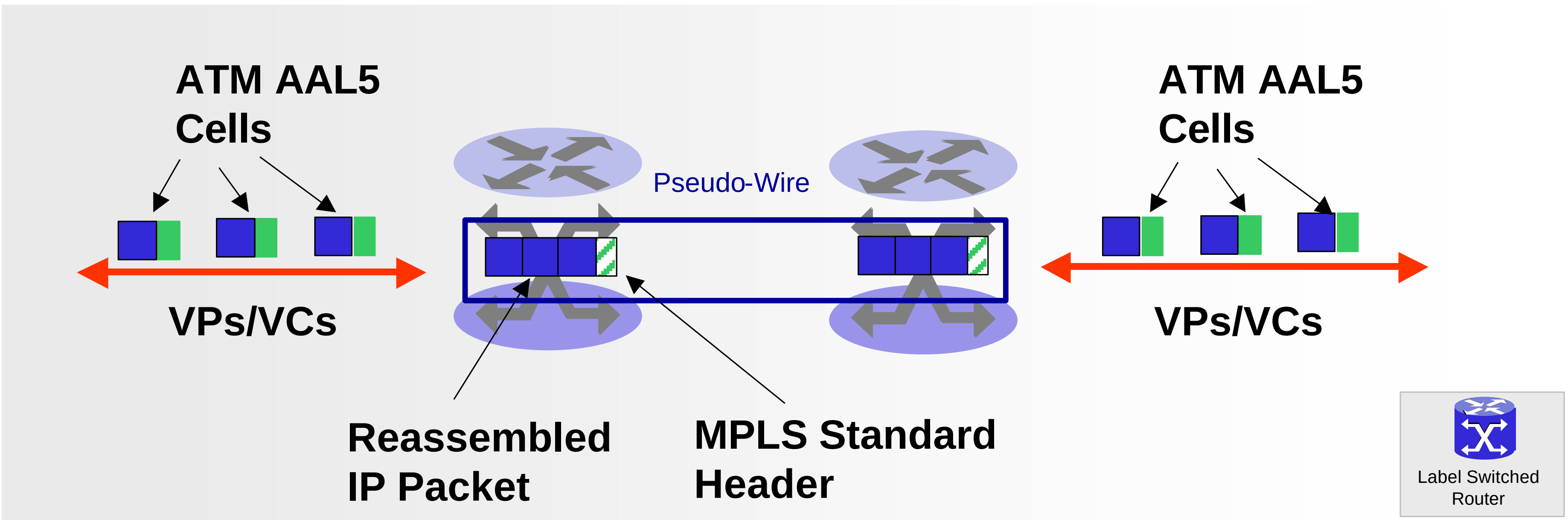


- MPLS and ATM networks as peers – PNNI-MPLS Interworking model

Agenda

- How Does ATM-MPLS Solution Work?
  - ✓ Data Plane
  - ✓ Control Plane
  - ✓ Solution Scalability
  - ✓ Resiliency
  - ✓ Management Plane

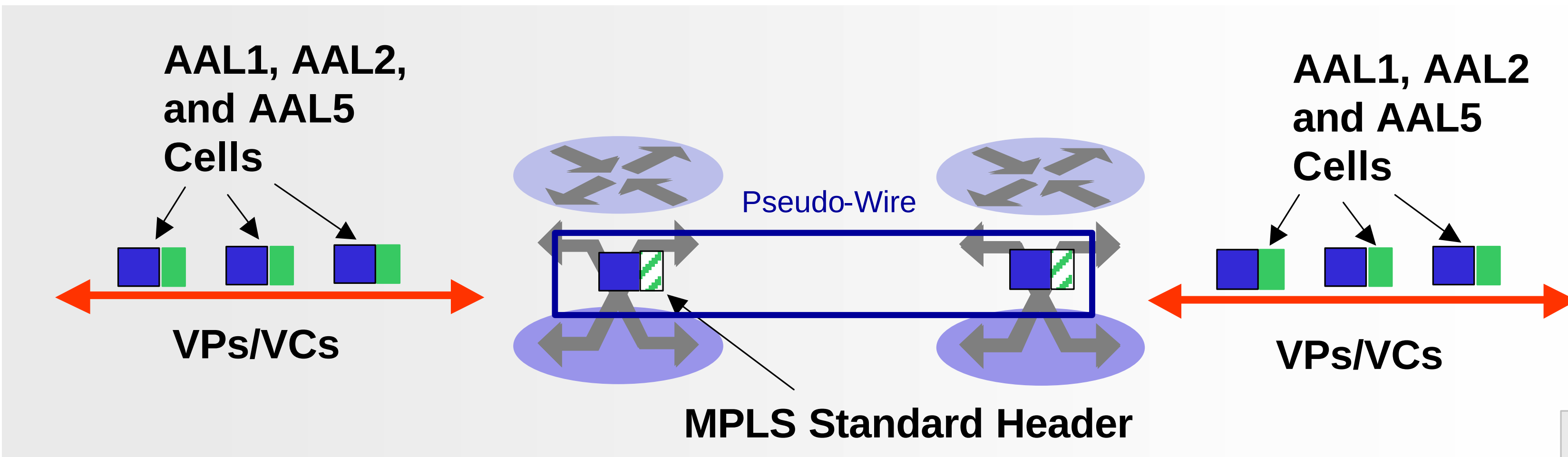
ATM Encapsulation – Packet Mode

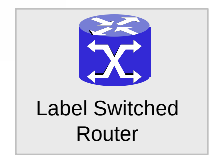


- PDU mode: Encapsulates PDU payload, pad and trailer
- SDU mode: Encapsulates the PDU payload

Draft-ietf-pwe3-atm-encap

ATM Encapsulation - Cell Mode





- One-to-One mode: uses different cell encapsulation & header formats for

  VCC and VPC services
  - ✓ Concatenation of cells of one VCC or VPC to one Pseudo-Wire for efficiency
- N-to-One mode: uses 4 octet ATM header to encapsulate all services (VCC and VPC)
  - ✓ Concatenation of cells of one or more VCCs or VPCs per Pseudo-Wire for efficiency
  - ✓ Sole IETF required encapsulation mode for ATM cells

draft-ietf-pwe3-atm-encap

ATM over MPLS: N to 1 Mode Cell Encapsulation

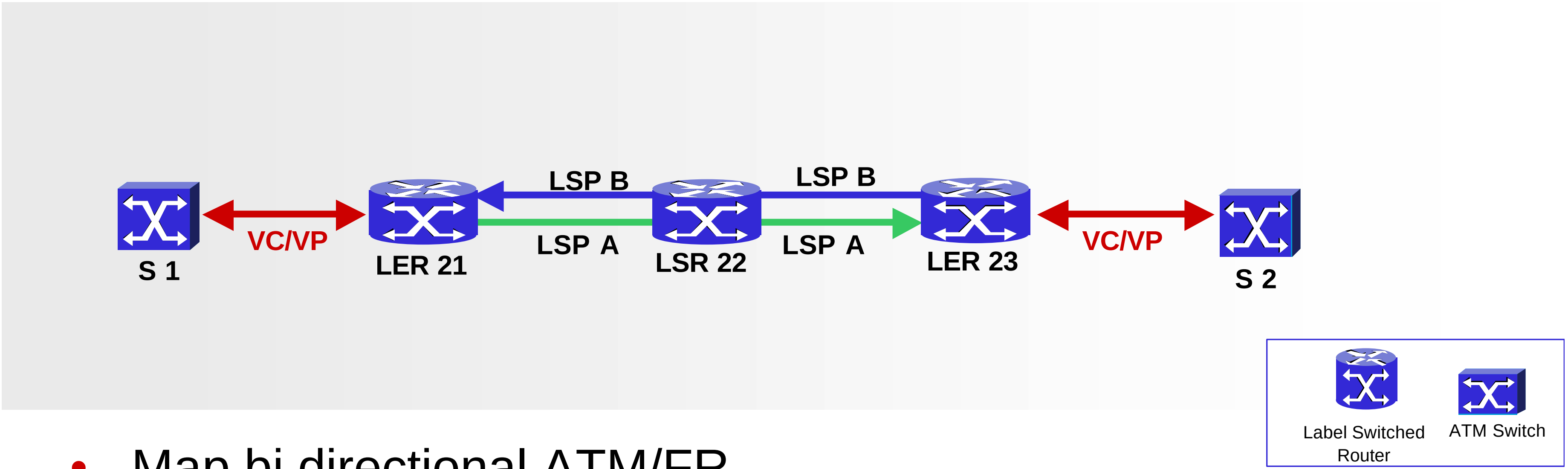
N to 1 Mode Multiple Cell Encapsulation

Control Word (optional)			
VPI	VCI	PTI	C
ATM Payload (48 bytes) “ “			
VPI	VCI	PTI	C
ATM Payload (48 bytes) “ “			

- Consists of the optional Control Word, VPI/VCI. Payload Type Identifier (PTI), and Cell Loss Priority (CLP in C field), and the ATM Cell Payload
- ATM cells are transported individually without a SAR process
- The ingress router MUST copy the VPI and VCI fields from the incoming cell
- EFCI and CLP bits carried in ATM cell header

Draft-ietf-pwe3-atm-encap

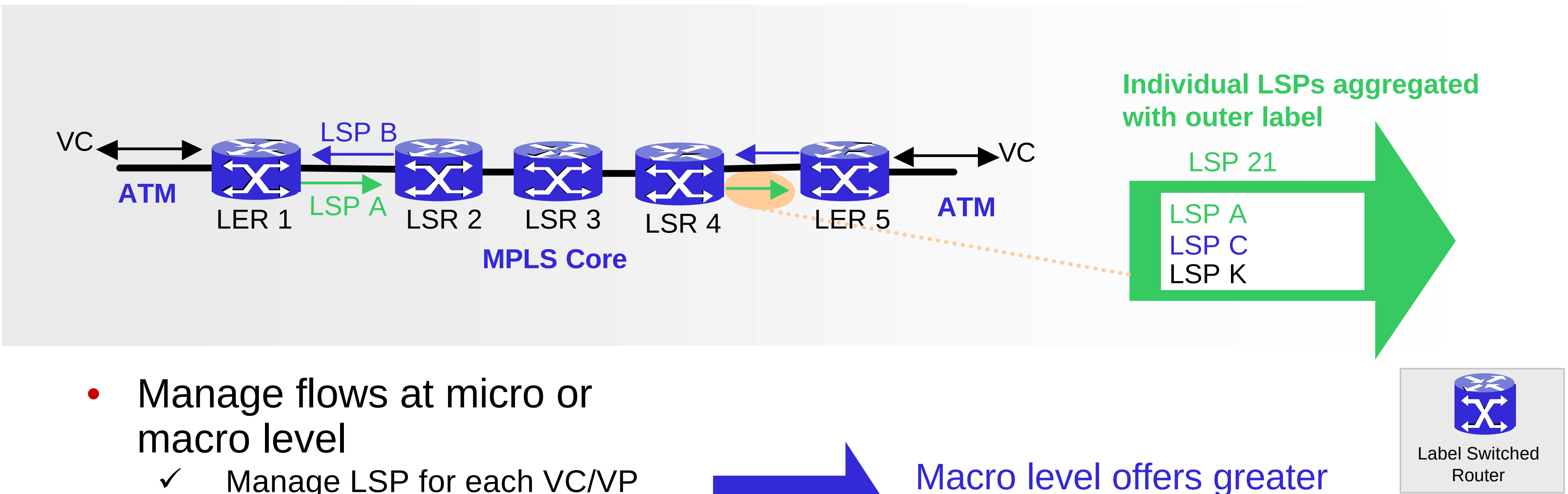
Cross-Connect ATM/FR Traffic to LSPs



- Map bi-directional ATM/FR traffic into pairs of uni-directional LSPs
- MPLS LSP acts as cross-connect trunk

Manual process impacts current operations cost

Solution Scaling

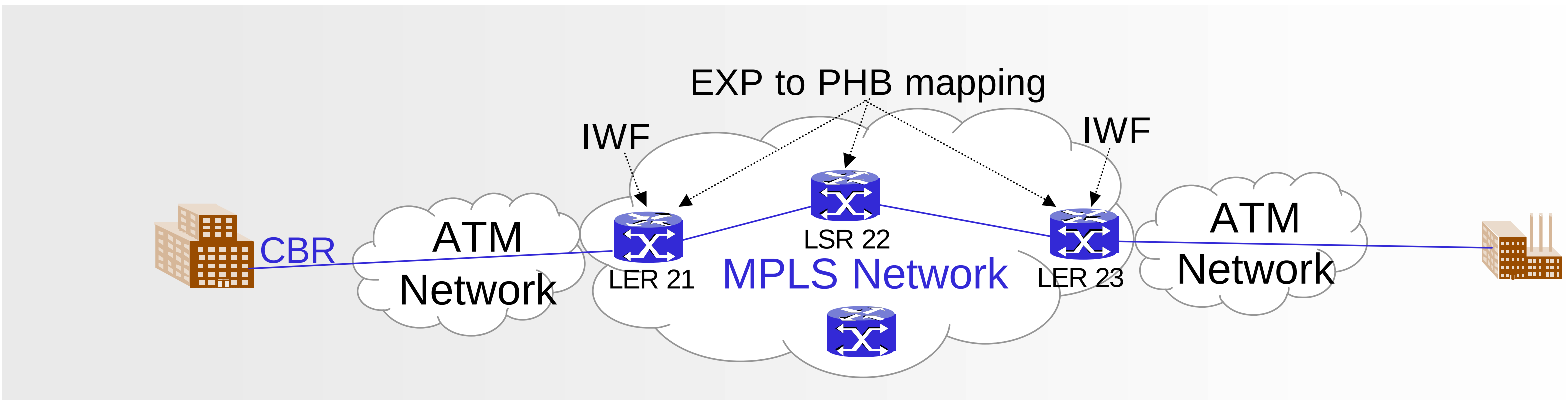


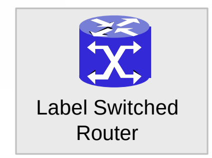
- Manage flows at micro or macro level
  - ✓ Manage LSP for each VC/VP across core
  - ✓ Aggregate LSP based on class of service and destination
- N-to-One Mode Encapsulation
  - ✓ Map multiple VCCs/VPCs per LSP
- 2 Label Stack
  - ✓ Inner and outer label
  - ✓ Initial establishment
  - ✓ Mapping of individual LSPs
  - ✓ Modify based upon traffic changes

Macro level offers greater scalability & performance

Manual process impacts current operations cost and network efficiency through sub-optimal paths

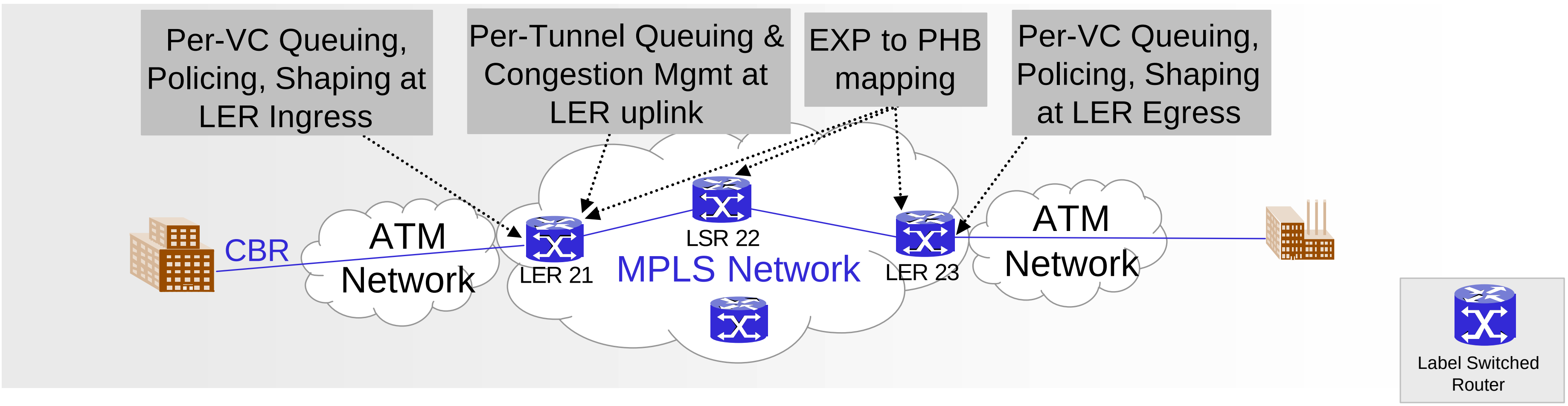
Mapping ATM QoS to MPLS





- QoS is a significant ATM/frame relay service attribute – particularly
  those with SLAs
  - ✓ End-to-end absolute characteristics
  - ✓ Standard ATM class of service: CBR, VBR-RT, VBR-NRT, UBR, ABR
- MPLS Network support
  - ✓ Traffic engineer path
  - ✓ Specify how traffic is relatively treated at each LSR (Per Hop Behavior (PHB))
    - Queue management, scheduling, congestion management
    - Use MPLS header EXP field (3 bit) to convey information
    - LSR maintains mapping from EXP to PHB

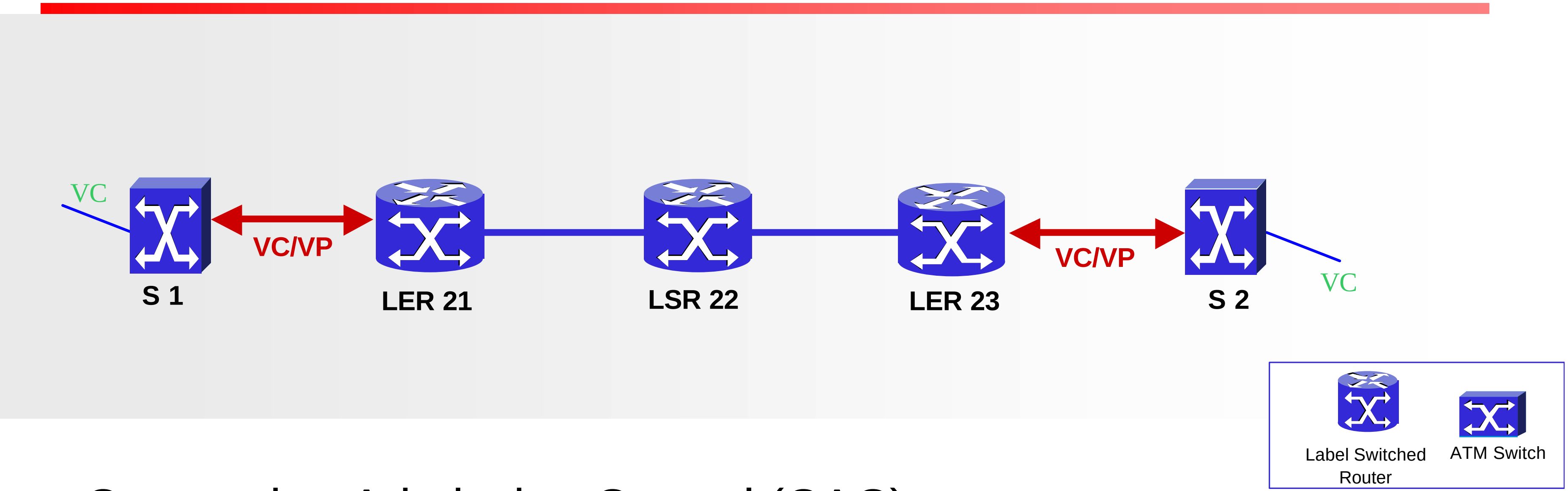
Mapping ATM QoS to MPLS



- MPLS solution is capable of providing the hard QoS some ATM traffic requires
  - ✓ Control Plane: required work underway (PNNI-MPLS Interworking Implementation Agreement)
  - ✓ Data plane:
    - Standards exist for traffic encapsulation
    - Queuing, shaping and scheduling can be applied to forwarding over MPLS LSPs (leverage ATM experience)
- Service provider defines how ATM QoS is supported in a MPLS network using a combination of:

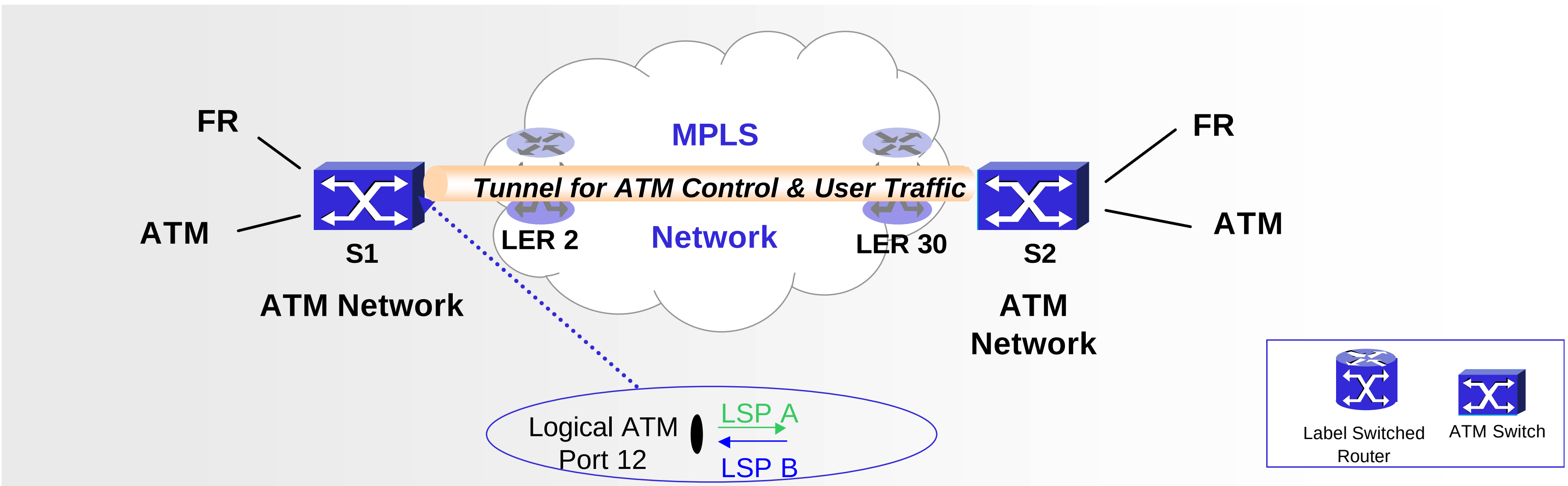
Traffic Engineering + PHBs + Signaling Interworking + Traffic Management

Connection Admission Control



- Connection Admission Control (CAC)
  - ✓ Use to determine availability and reserve bandwidth
  - ✓ Separate functions in ATM/FR and MPLS domains
  - ✓ Manually provision ATM/FR CAC information (bandwidth, delay, cell/packet loss requirements, …) associated with a VC into MPLS domain
  - ✓ Integrated across domains in future?

ATM-MPLS Network Interworking

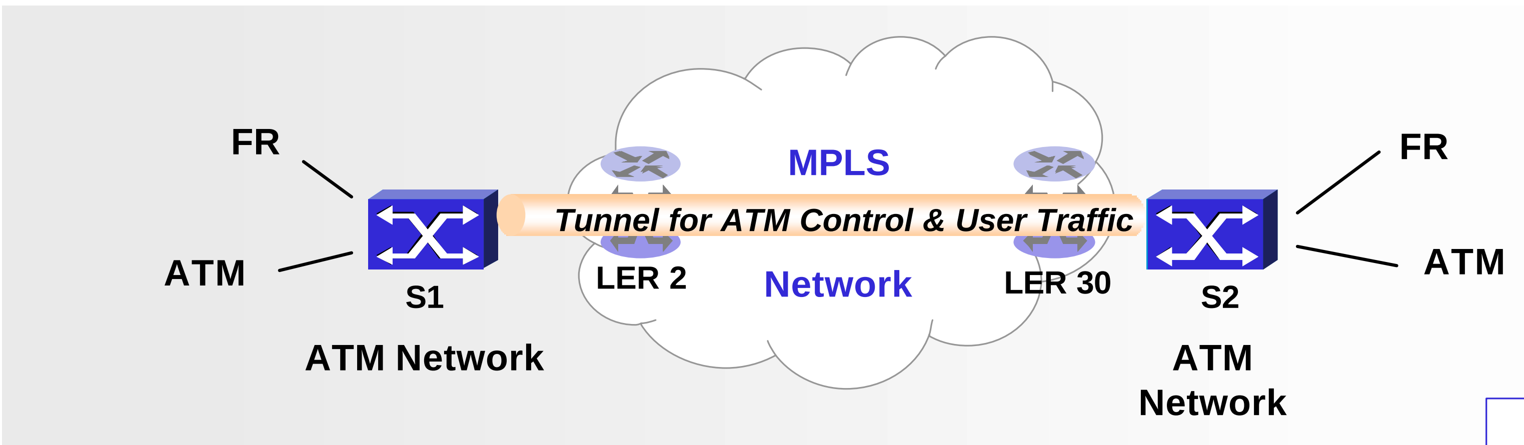


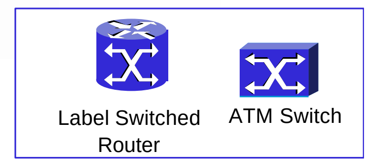
- MPLS network appears as a tunnel to the ATM network for traffic transport
- Tunneling function for control and user traffic
- Pair of transport LSPs modeled to ATM signaling/routing as a logical ATM port

ATM Forum specification "ATM-MPLS Network Interworking, Version 2.0, fb-aic-0178.001, August 2003";

ATM Forum specification "ATM-MPLS Network Interworking Signalling, Version 1.0, fb-cs-0197.000, August 2003"

ATM-MPLS Network Interworking





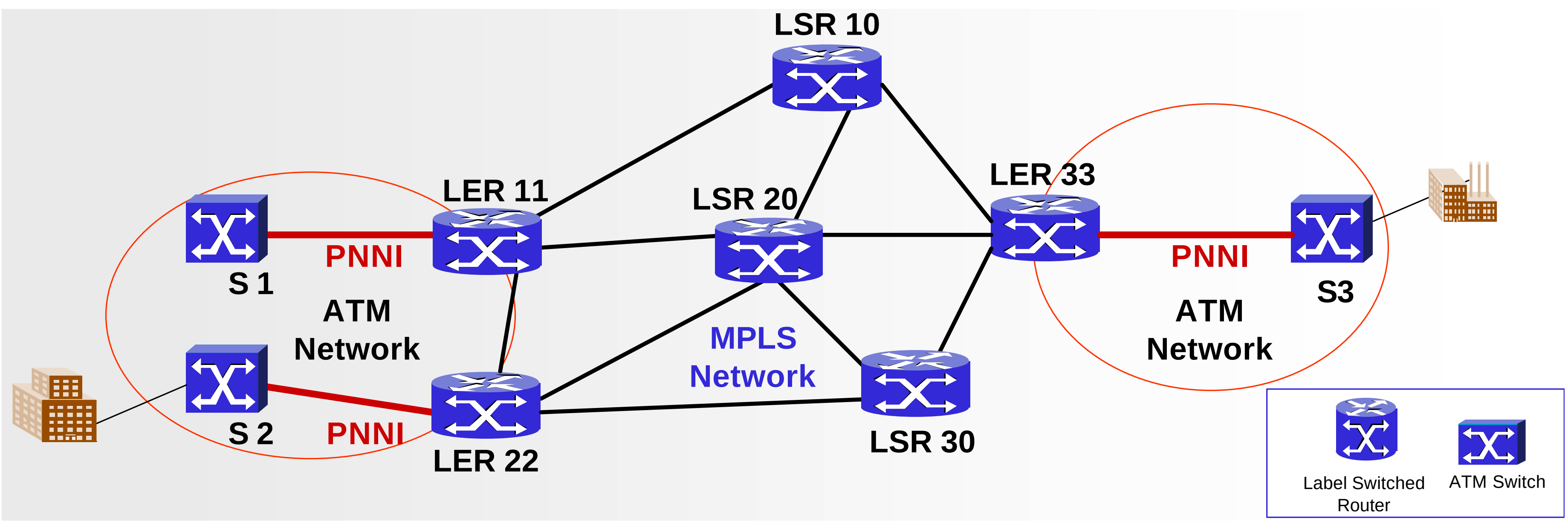
- Extend current PNNI messages to distribute MPLS labels
- Three modes of encapsulation defined for ATM-MPLS-ATM
  - ✓ Single cell encapsulation (mandatory)
  - ✓ Concatenated cell encapsulation
  - ✓ Frame encapsulation (CLP bit and EFCI state not preserved for AAL5)
- N-to-one mode defined in separate specification

ATM Forum specification "ATM-MPLS Network Interworking Signalling, Version 1.0, fb-cs-0197.000, August 2003"

ATM Forum specification "ATM-MPLS Network Interworking, Version 2.0, fb-aic-0178.001, August 2003";

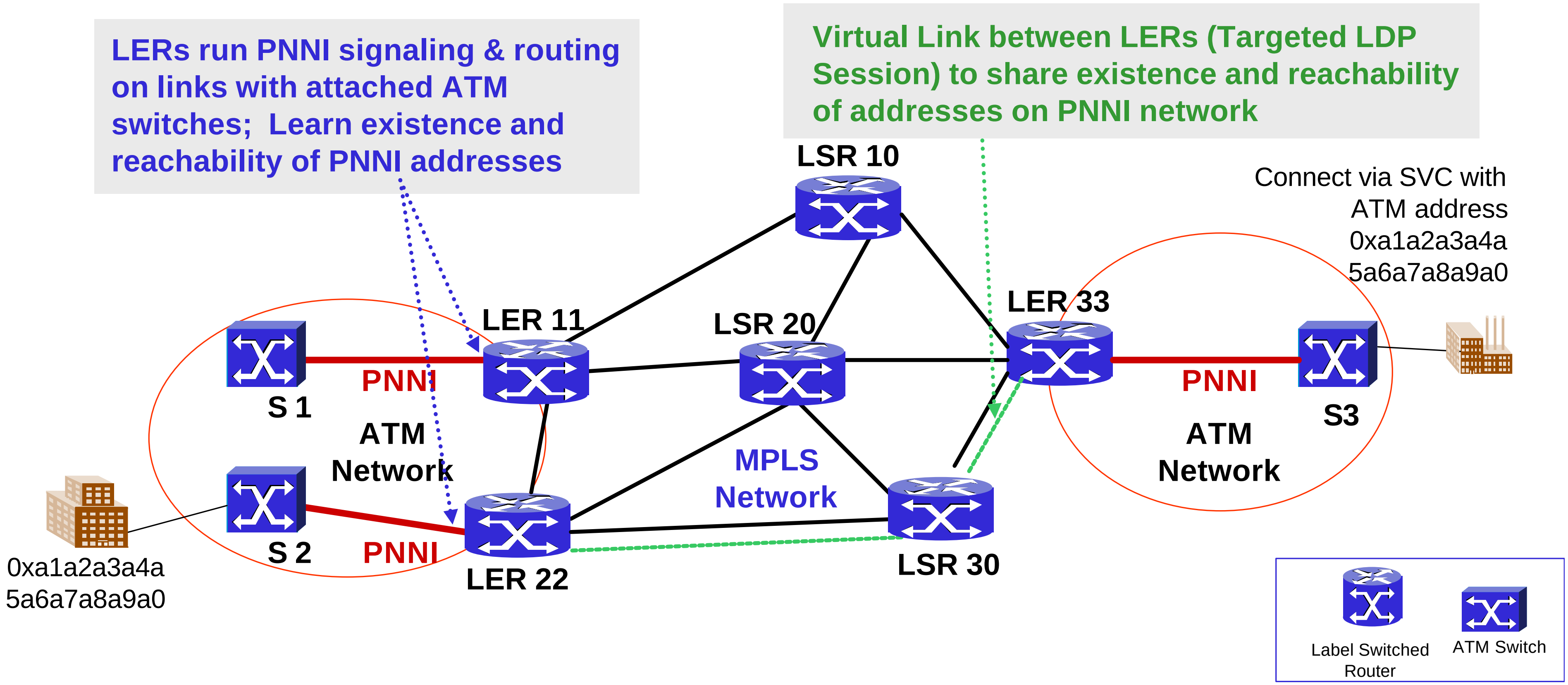
ATM Forum specification "ATM-MPLS Network Interworking (N-to-one mode), Version 1.0, fb-aic-0196.000, July 2003"

PNNI-MPLS Interworking



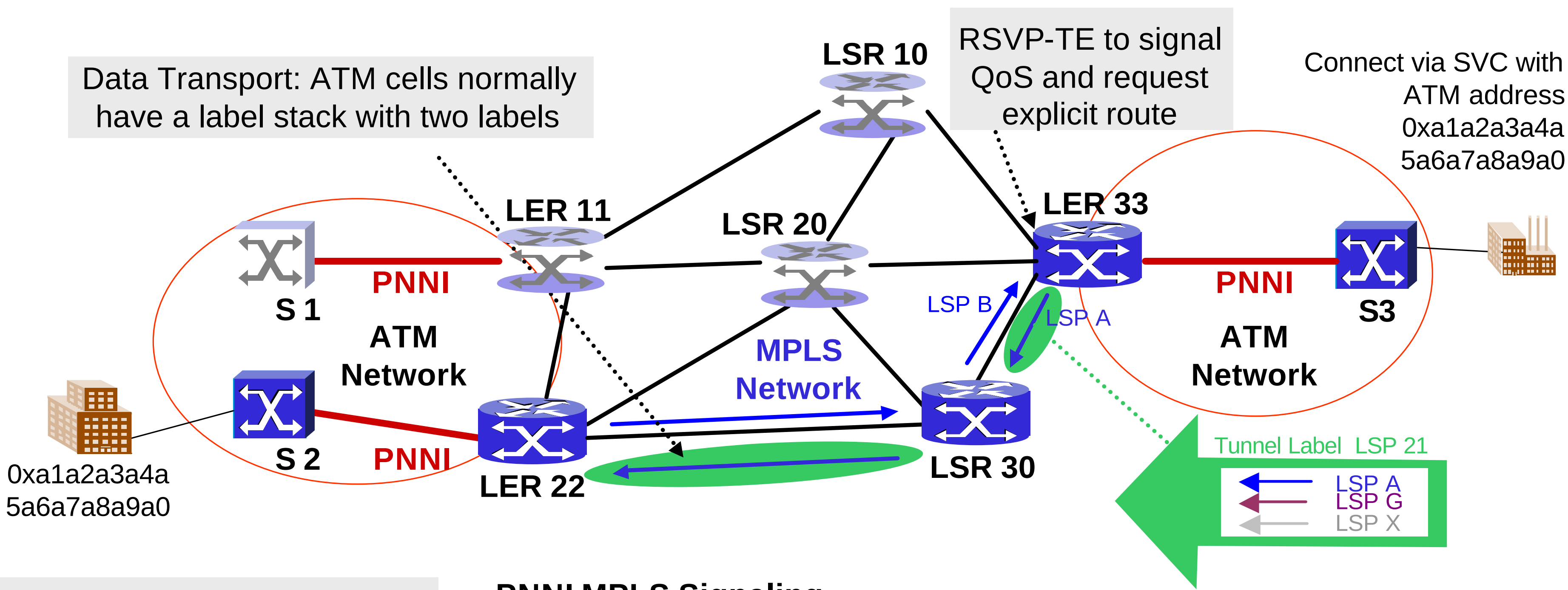
- PNNI-MPLS Interworking Implementation Agreement (baseline text - MPLS2002.133)
- Purpose: Seamless integration of MPLS with ATM PNNI signaling and routing
  - ✓ Propagation of PNNI routing information between MPLS network edge switches (LERs)
  - ✓ Signaling interworking at LERs that translates between PNNI signaling requests and VC label operations

PNNI-MPLS Interworking – How it works



MPLS & Frame Relay Alliance "PNNI-MPLS Interworking Implementation Agreement (second straw ballot text - MPLS2003.087,00)"

PNNI-MPLS Interworking – How it works (continued)



PNNI-MPLS Signaling

Setup

Label Mapping

Label Mapping

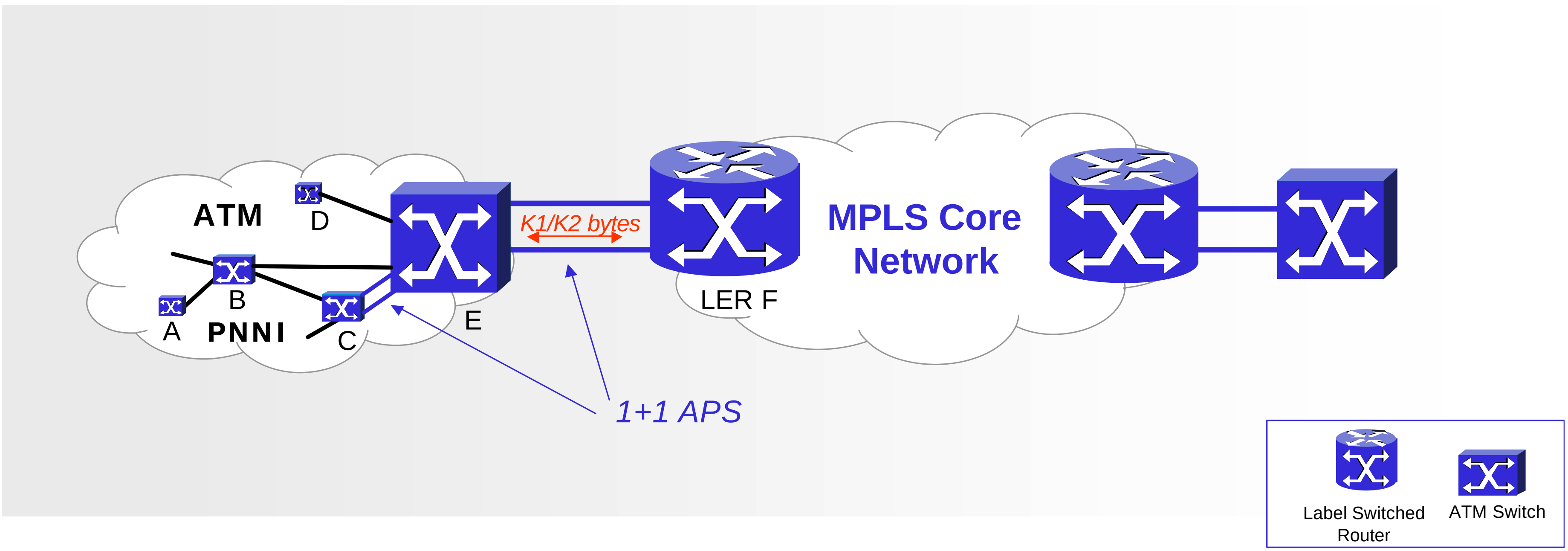
Call Processing

Connect

Label Distribution Protocols
- RSVP-TE: Tunnels
- BGP Ext: Labels at bottom of stack
- LDP: Tunnels & Labels at bottom of stack (Targeted LDP mode)

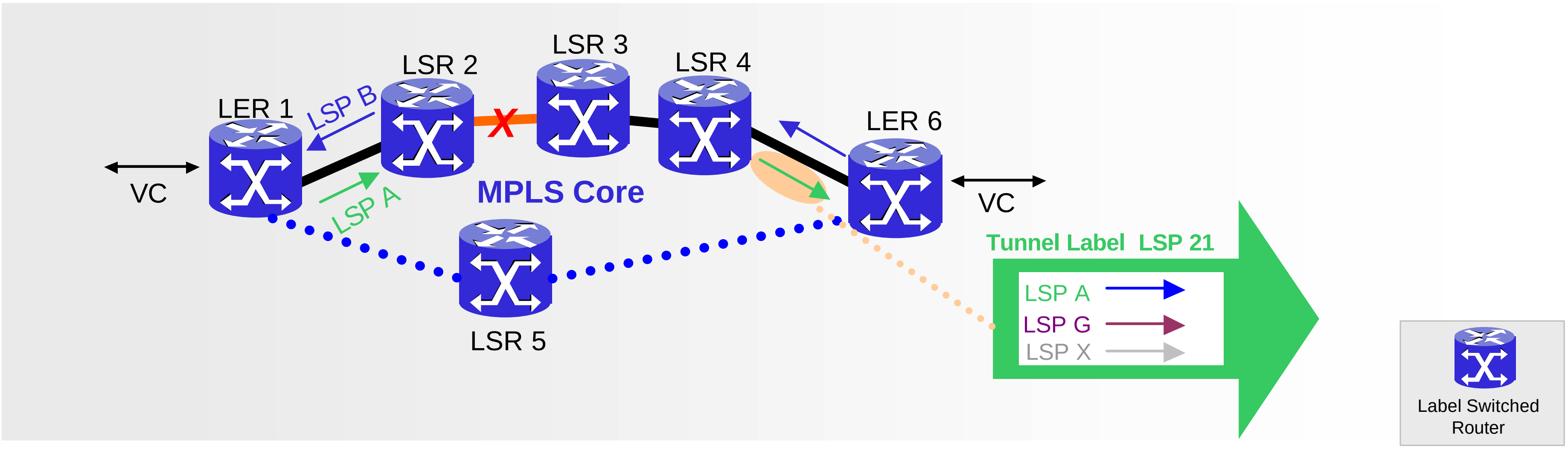
MPLS & Frame Relay Alliance "PNNI-MPLS Interworking Implementation Agreement (second straw ballot text - MPLS2003.087,00)"

Resiliency



- Today's ATM network solution: 1+1 APS and PNNI domain re-routing (DBR)
- 1+1 APS option for link protection between ATM & MPLS devices

Resiliency - Restoration

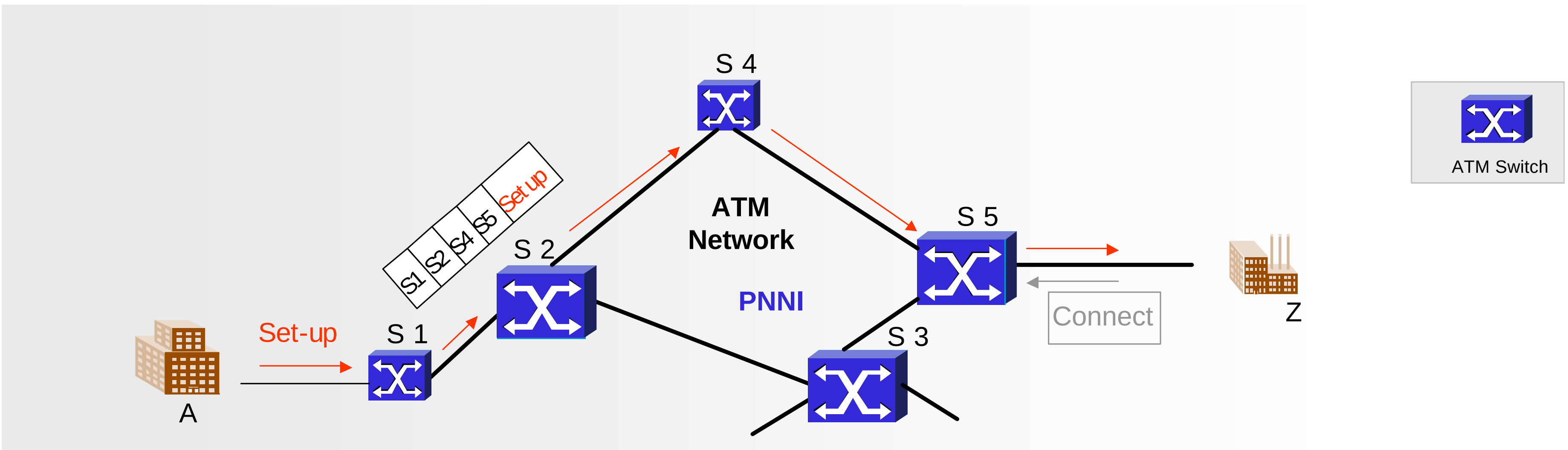


- Core flow management at micro or macro level (2 label stack)
- Restoration at multiple layers
  - ✓ MPLS
  - ✓ ATM (PNNI)
  - ✓ SONET/SDH (1+1 APS)
- Protocol graceful restart capabilities

Macro level offers greater scalability, performance & reduces manual back-up path provisioning time/expense

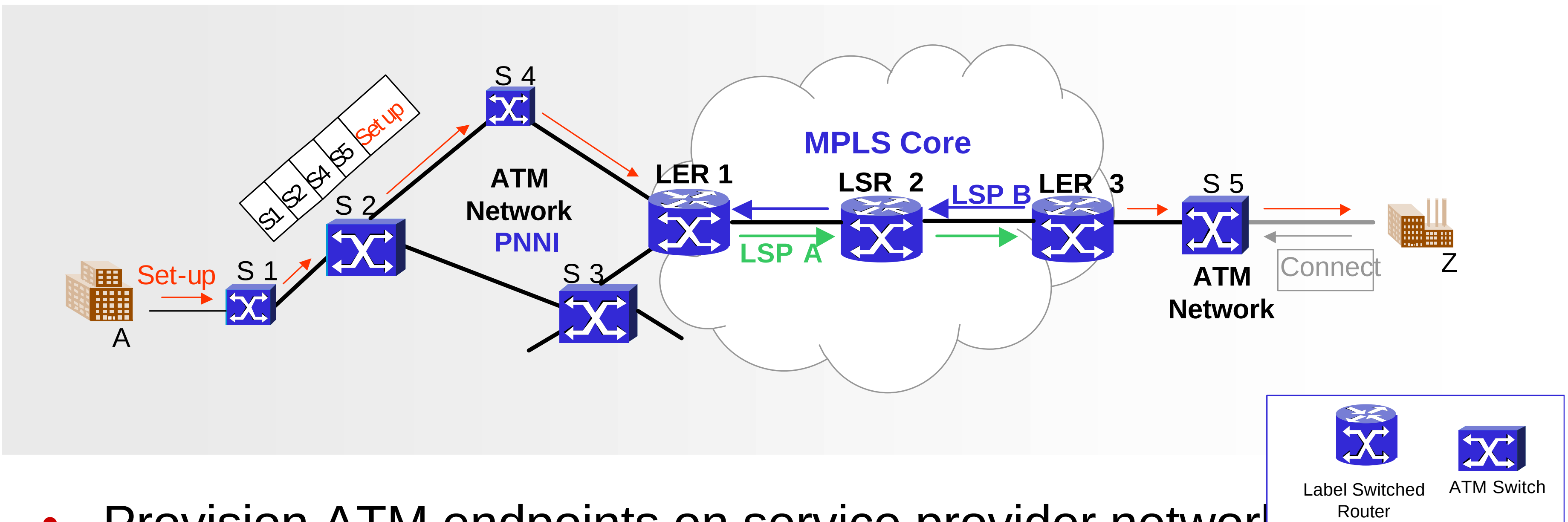
Manual process (engineering/ provisioning) impacts operations cost and network efficiency

Provisioning ATM Service - Today



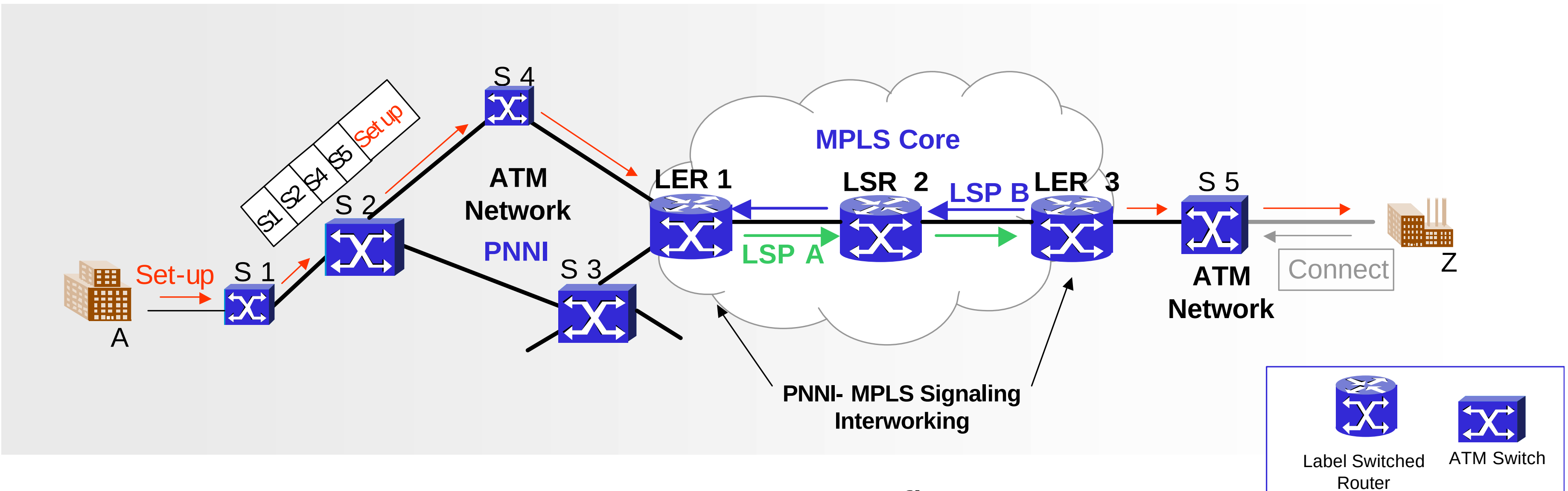
- PNNI network using SPVCs
- Provision endpoints on service provider network
- Source node selects path

Provisioning ATM Service with MPLS Core - Today



- Provision ATM endpoints on service provider network
- ATM source node selects path
- Provision cross-connect of bi-directional VCs into uni-directional LSPs

Provisioning ATM Service with MPLS Core – Longer Term

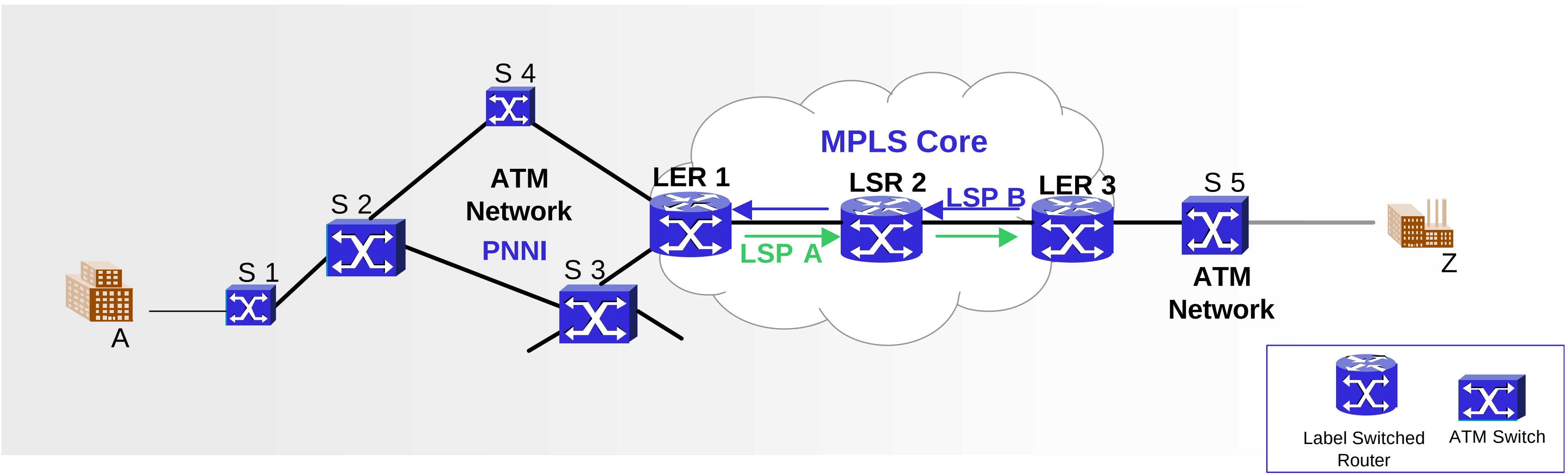


- Provision ATM endpoints on service provider network
- ATM source node selects path
- PNNI- MPLS signaling interworking
- Automatic cell or packet mode encapsulation based upon ATM CoS

Benefits

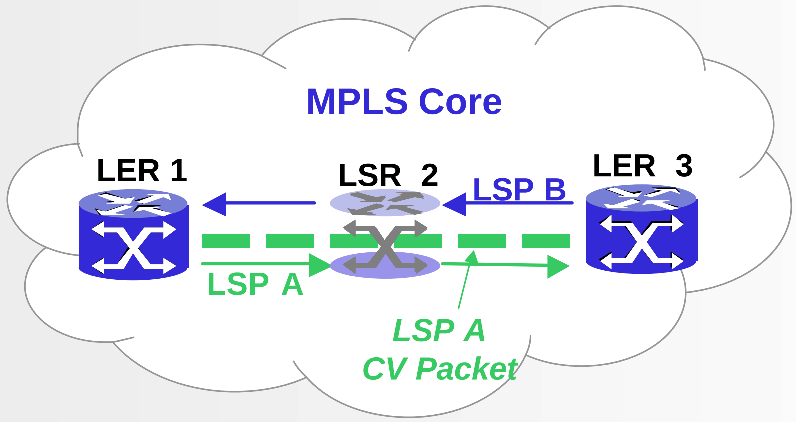
- No change in new ATM service provisioning activity/expense
- Multi-domain path optimization

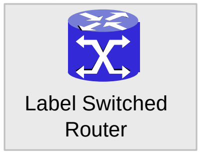
Fault Diagnostics



- "ATM type" loop backs in ATM domain to verify connectivity and isolate troubles
  - ✓ Encapsulate OAM cells for loop back across entire core
  - ✓ ATM segments
  - ✓ ATM – MPLS segment: Potential future capability of LER to terminate and respond?

Fault Detection

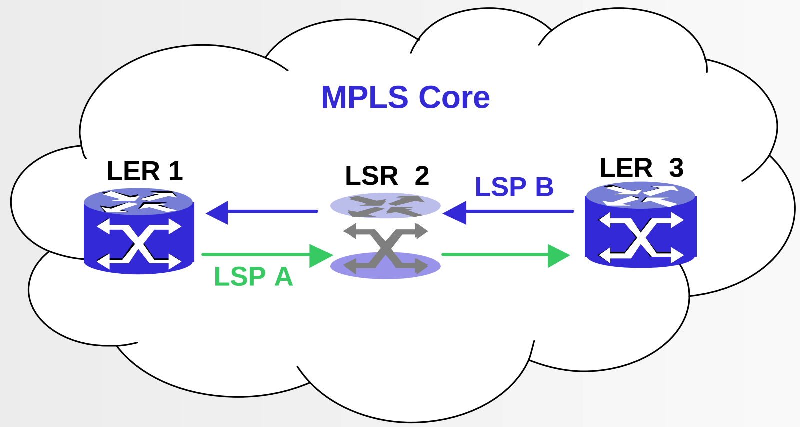


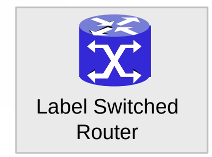


- Connectivity Verification (CV) using OAM packets
  - ✓ Verify entire MPLS path
  - ✓ Verify a segment (Layer N): create new server layer LSP at Layer N+1
- Forward Defect Indication (FDI) using OAM packets
  - ✓ Generated in response to detecting defects from CV flow
  - ✓ Utilize to suppress alarms in layered networks above the level of defect occurrence
- Backward Defect Indication (BDI) using OAM packets
  - ✓ Inform upstream end of LSP of a downstream defect
  - ✓ Utilize for single-ended operations, indication of protection switching and bi-directional network performance

ITU Y.1711

Fault Diagnostics

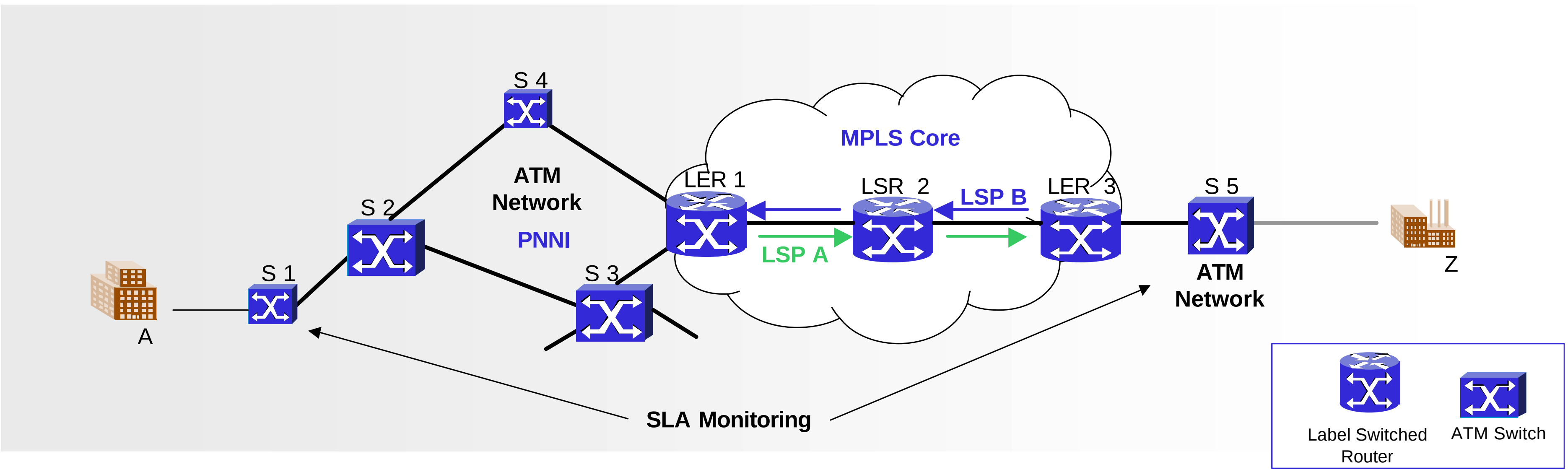




- Expanding ITU Study Group 13 work on MPLS OAM
- LSP Ping to verify basic connectivity (similar to ICMP echo request/reply)
  - ✓ Tests whether packets in a specific FEC egress on LER that supports the FEC
  - ✓ Reply options: none, via IP, control plane or partner LSP (other half of bi-directional PW)
  - ✓ Repeat for other other direction
- Tunnel Trace
- Continuing standards work on integrating ATM higher level procedures and diagnostic applications in ATM-MPLS solutions required to sustain current profitability

ITU Y.17fw (Framework for MPLS Management)

SLA Monitoring

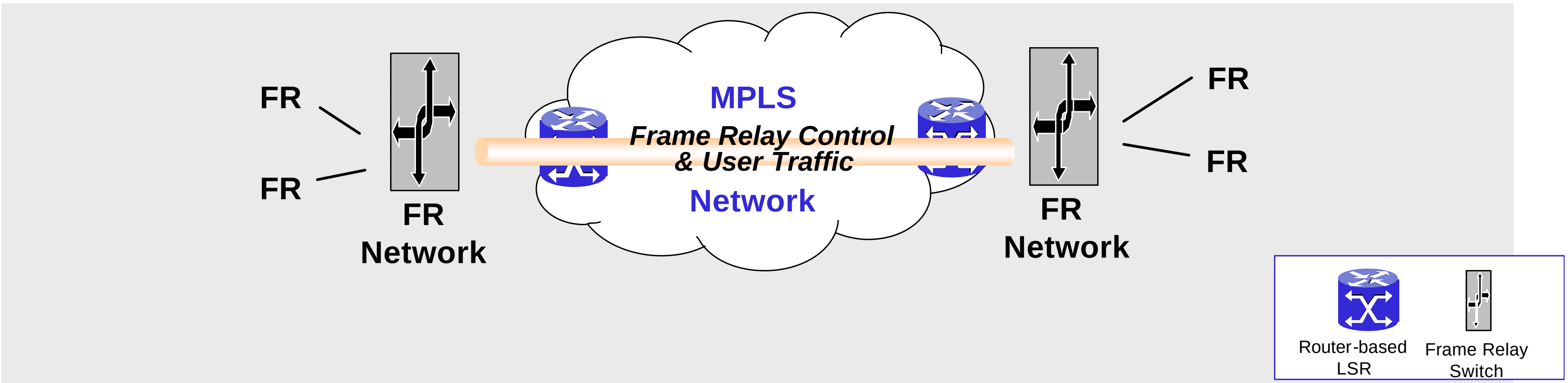


- Service specific monitoring continues at edge
  - ✓ Current Customer Network Management (CNM) tools continue in use by businesses
    - Performance monitoring
    - Configuration of specific resources
- MPLS network is transparent

Agenda

- How Does Frame Relay-MPLS Solution Work?
  - ✓ Overview
  - ✓ Data Plane
  - ✓ Control Plane
  - ✓ Management Plane

Frame Relay – MPLS Migration Overview

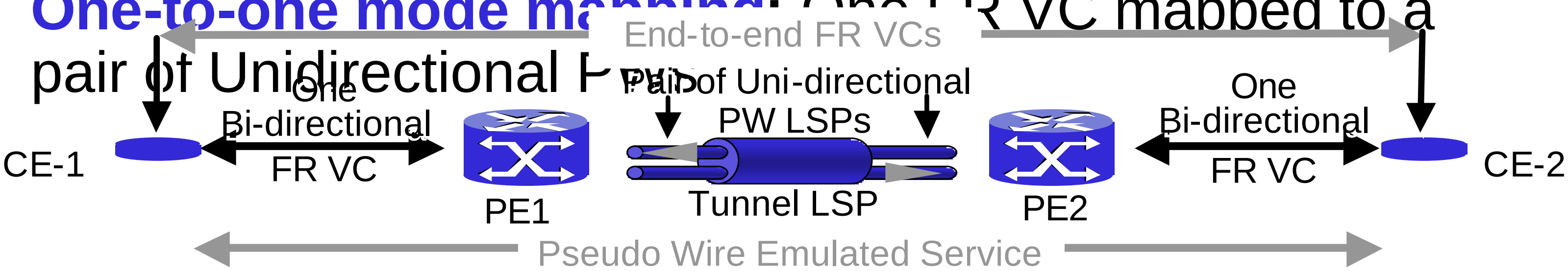


- Frame Relay services over core MPLS network
- Ongoing area of ITU-T SG17 (Draft new Recommendation X.84 – Support of frame relay services over MPLS core networks) and IETF work
- MPLS & Frame Relay Alliance – 8 of 8 contributions to ITU-T accepted (9/03)

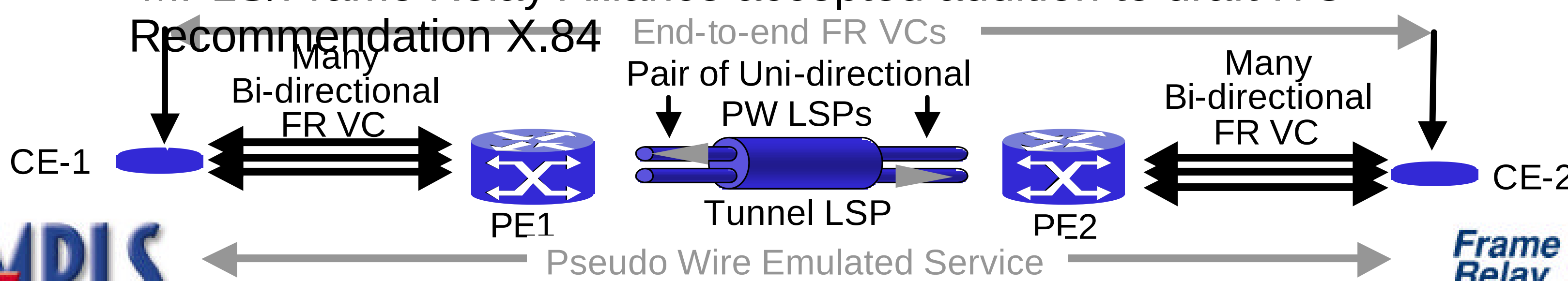
Frame Relay Encapsulation

Two Mapping modes defined between FR VCs and Pseudo Wires (PWs)

- **One-to-one mode mapping:** One FR VC mapped to a pair of Unidirectional PWs

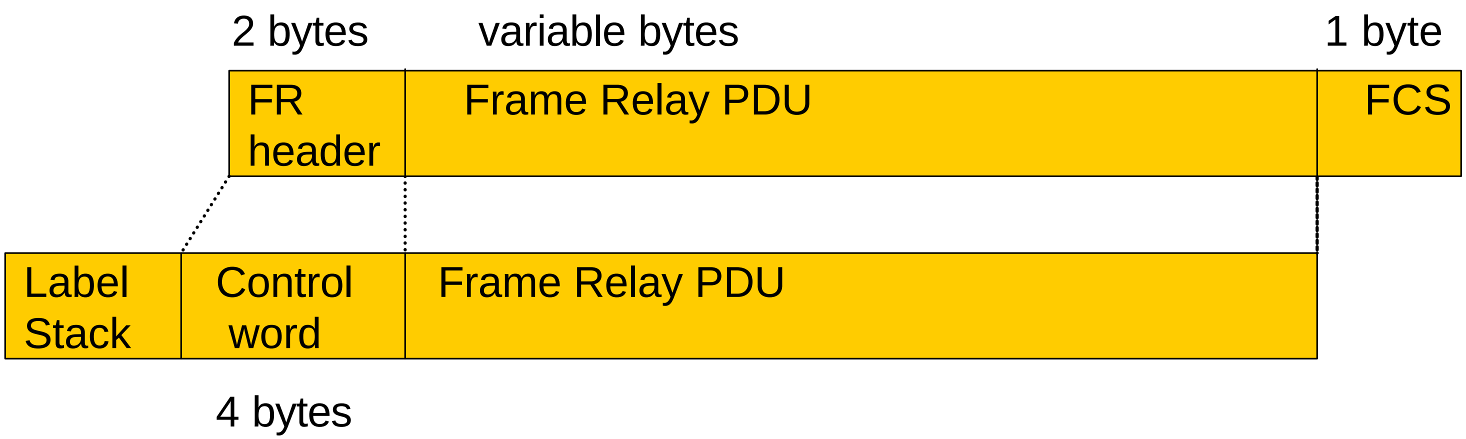


- **Port mode mapping (Optional):** Many FR VCs mapped to a pair of Unidirectional PWs
  - MPLS/Frame Relay Alliance accepted addition to draft ITU Recommendation X.84



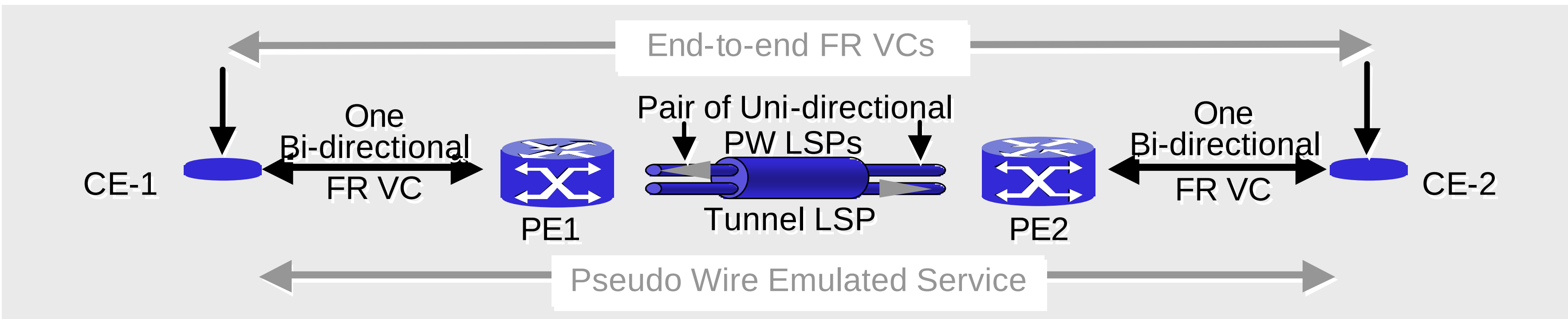
draft-ietf-pwe3-frame-relay-01.txt

Frame Relay over MPLS



- The FR PDU is transported without the FR header or the FCS. The control word is REQUIRED; however, its use is optional
- The BECN, FECN, DE and C/R bits are carried across the network in the control word. LERs MAY change these bits
- The MPLS edge LSR MUST provide FR PVC status signaling to the FR network
- If MPLS edge LSR detects a service affecting condition as per X.36, it MUST withdraw the label that corresponds to the FR DLCI

Frame Relay Encapsulation – One-to-one Mode



MPLS/Frame Relay Alliance accepted addition of optional fragmentation procedures to ITU Draft new Recommendation X.84

- May use when combined size of payload and associated headers exceeds network path maximum transmission unit (MTU) – when MTU management methods fail
- Negotiated between local and remote PEs through signaling or provisioned
- Use sequence number field and two reserved bits (8, 9) in control word

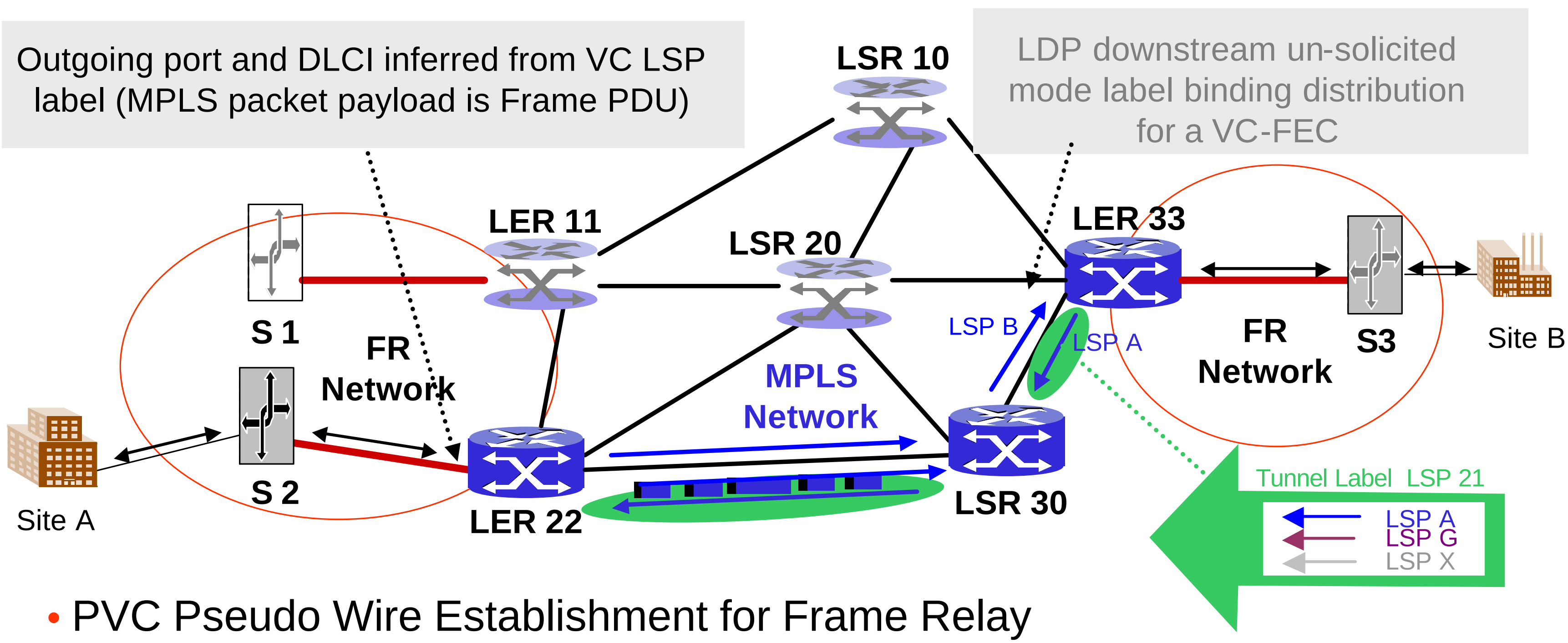
ITU Draft new Recommendation X.84 (consent stage of approval process)

PVC Pseudo Wire Establishment for Frame Relay

- Control signaling being worked by IETF
  - ✓ draft-ietf-pwe3-control-protocol-03.txt
  - ✓ IANA assignment of code points for FEC element 128 and Pseudo Wire Status TLV pending
- **MPLS/Frame Relay Alliance proposed pseudo wire signaling specification text to ITU Draft new Recommendation X.84**
  - ✓ Specifies PVC status monitoring for one-to-one mode
  - ✓ Also describes procedures for establishing VC LSP labels for transport using one-to-one mode for frame relay connections
  - ✓ Intend to align with IETF work
  - ✓ Additional work and contributions with be undertaken in the MPLS & Frame Relay Alliance to finalize this work
  - ✓ Proposed for ITU last call in March '04 if IETF control protocol is stable

draft-ietf-pwe3-control-protocol-03.txt (work in progress)
ITU Draft new Recommendation X.84 (consent stage of approval process)

PVC Pseudo Wire LSP Signaling – How it works

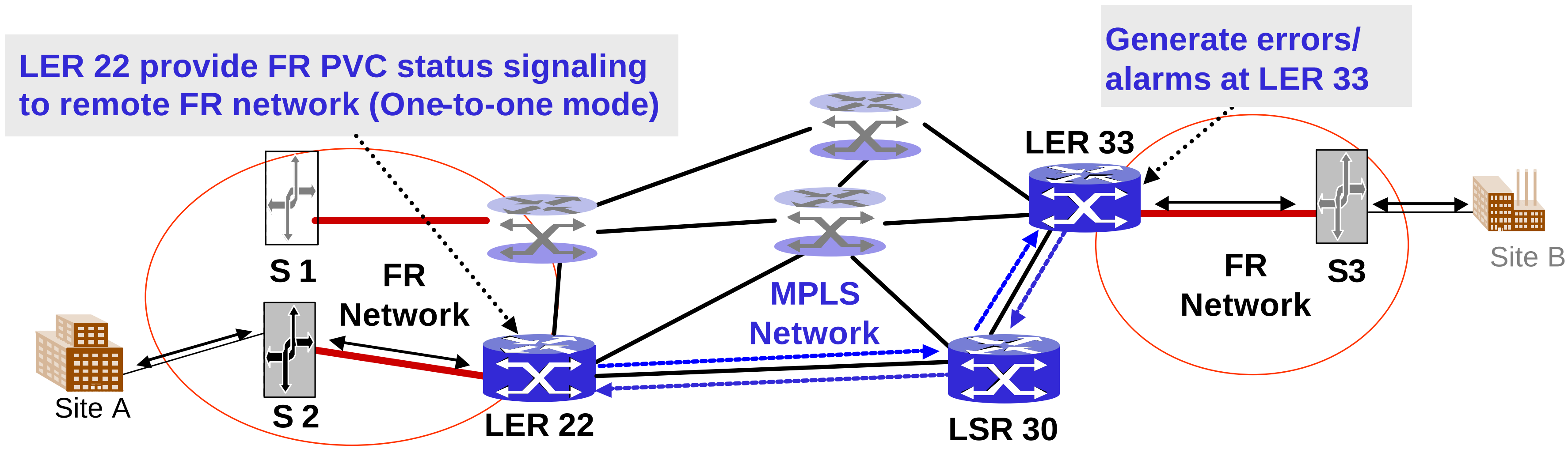


- PVC Pseudo Wire Establishment for Frame Relay
- Bi-directional Tunnel LSP transports FR PDUs across MPLS network
- Focus on Frame Relay PVCs (doesn't preclude future enhancements for SVC and SPVC emulation)

MPLS & Frame Relay Alliance proposed Information Appendix as an Addendum to ITU Draft new Recommendation X.84 (consent stage of approval process)

Draft-ietf-pwe3-control-protocol-03 (work in progress)

PVC Status Monitoring – How it works



- **One-to-one Mode**:
  - ✓ Status reporting between PEs when PVC is created, deleted and/or state change (active/in-active)
  - ✓ PVC status/attribute information from management plane or attached UNI/NNI mapped to LDP operational status TLV
- **Port Mode:** Use existing FR status signaling and transparently provide information to peer - Frame DTE or CE monitors PVC status an places information on DLCI 0

Frame Relay and ATM Migration to MPLS Summary

- Industry standard basic transport capabilities (Ex: encapsulation) are available
- Emerging industry standards/agreements from groups such as the MPLS & Frame Relay Alliance on ATM/FR-MPLS inter-domain interoperability critical for profitable ATM/FR SLA support
  - ✓ Signaling interworking
  - ✓ QoS
  - ✓ OAM

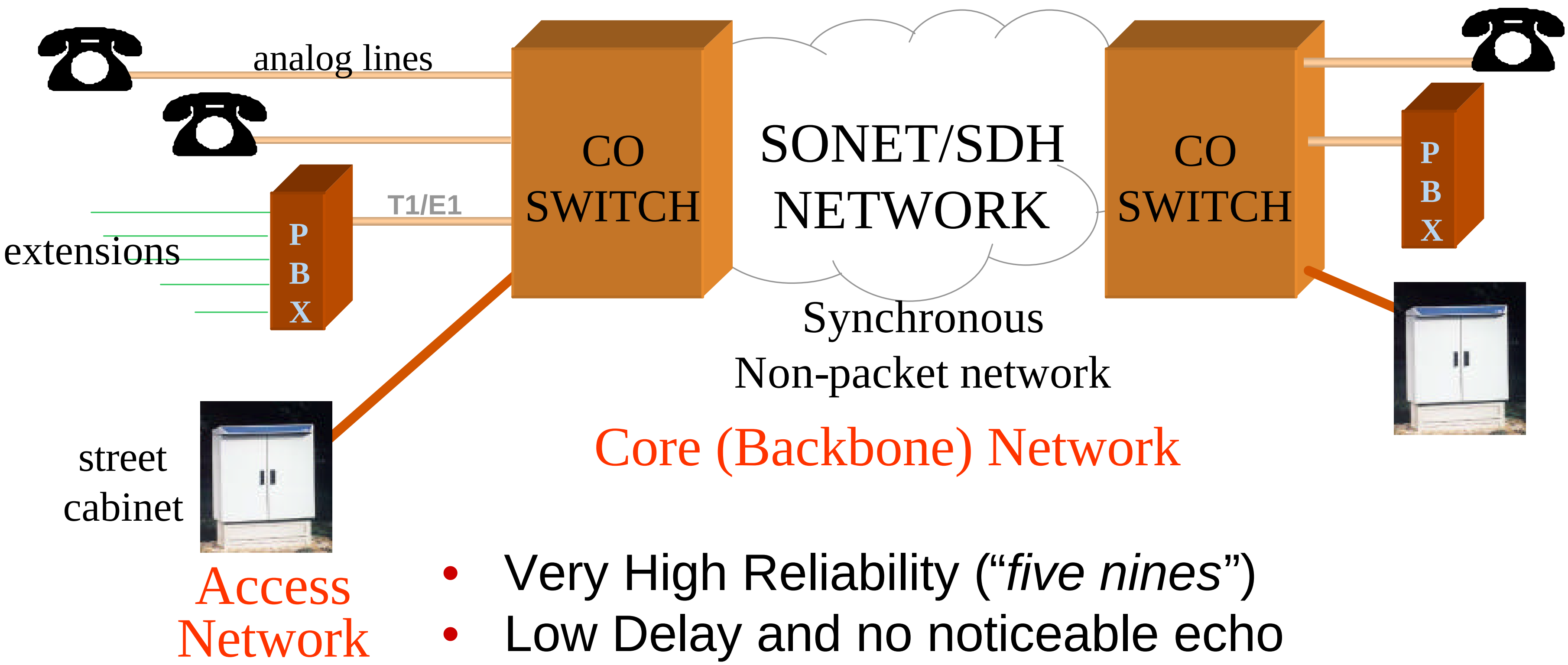
Migrating TDM and Voice to MPLS

Section 5

TDM Migration Agenda

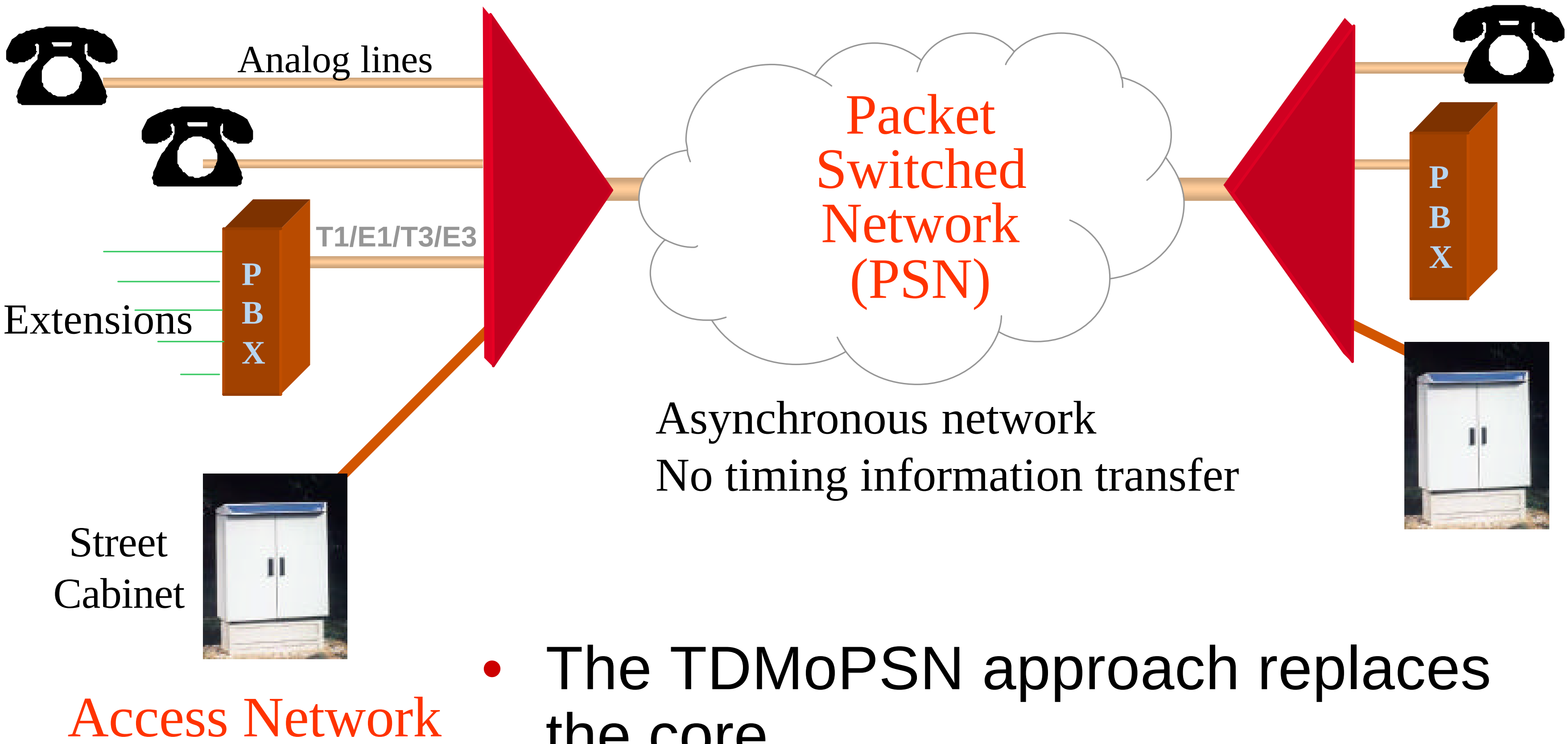
- TDM transmission
  - ✓ Classic TDM network vs. PSN
  - ✓ Using MPLS
  - ✓ Telephony is more than voice
- TDM over MPLS (TDMoMPLS)
  - ✓ Processing
  - ✓ Format and payload types
- TDM timing
  - ✓ Delay and packet delay variation
  - ✓ Jitter buffers
  - ✓ Clock Recovery

Classic TDM Telephony



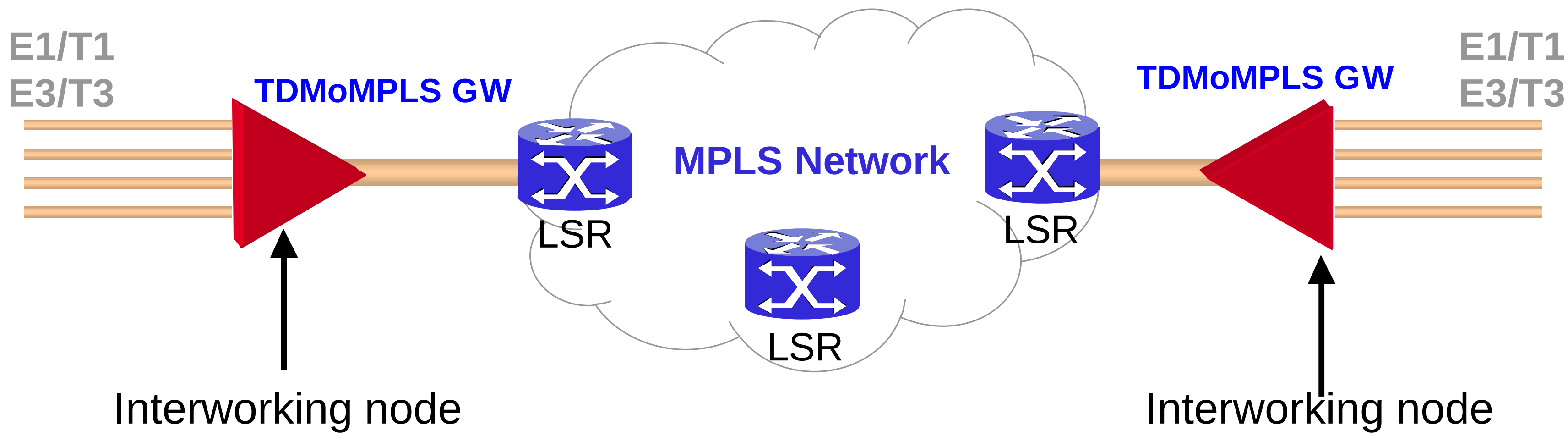
- Very High Reliability ("*five nines*")
- Low Delay and no noticeable echo
  - ✓ Echo control (cancellers) on toll switches
- BITS clock in each office provides Timing
- Mature Feature Set (3,000 features) and Signaling Protocols

TDM Transported over PSN



- The TDMoPSN approach replaces the core
 with a packet (IP or MPLS) network
- The access networks and their protocols remain

TDM over MPLS (TDMoMPLS) Reference Model

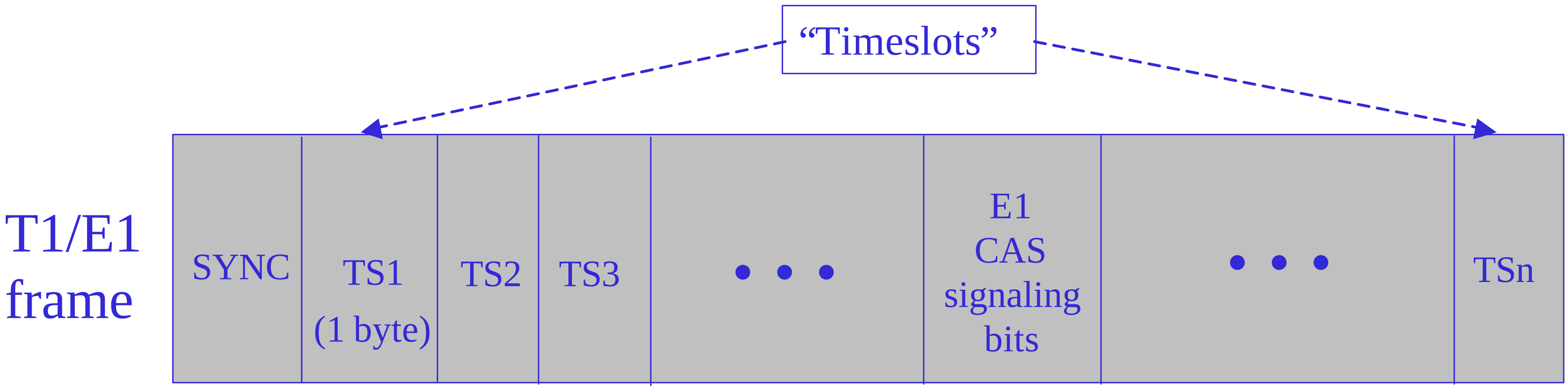


MPLS network connects two TDM networks to provide network interworking

Why MPLS?

- Emulated services have QoS and TE requirements
  - ✓ IP is basically a “best effort” service
  - ✓ diffserv and RSVP extensions not prevalent
  - ✓ MPLS can provide TE guarantees
  - ✓ RSVP-TE allows TE signaling
- MPLS LSPs can support rich set of TDM trunk group related features while adding new capabilities
  - ✓ Ex: MPLS label stack provides natural multiplexing method

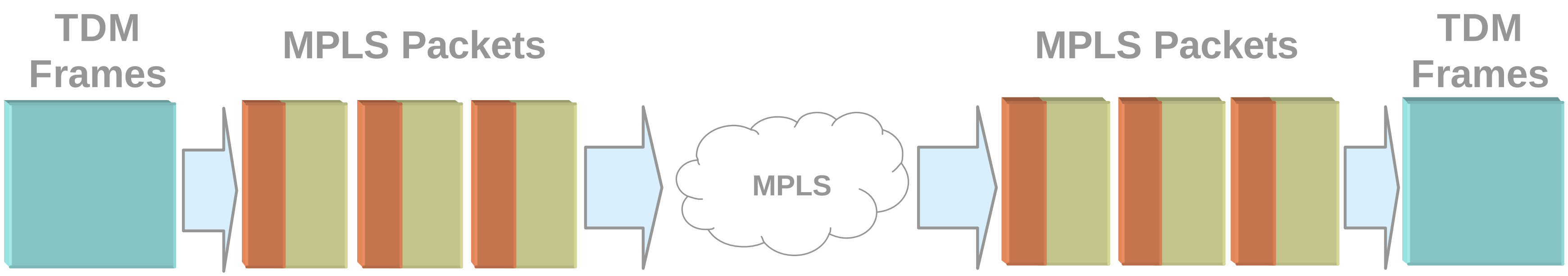
TDM is more than just “voice”



What needs to be transported end to end?

- Voice (telephony quality, low delay, echo-less)
- Tones (for dialing, PIN numbers, inter-exchange signaling, etc.)
- Fax and modem transmissions
- Telephony signaling transferred transparently

TDMoMPLS Processing



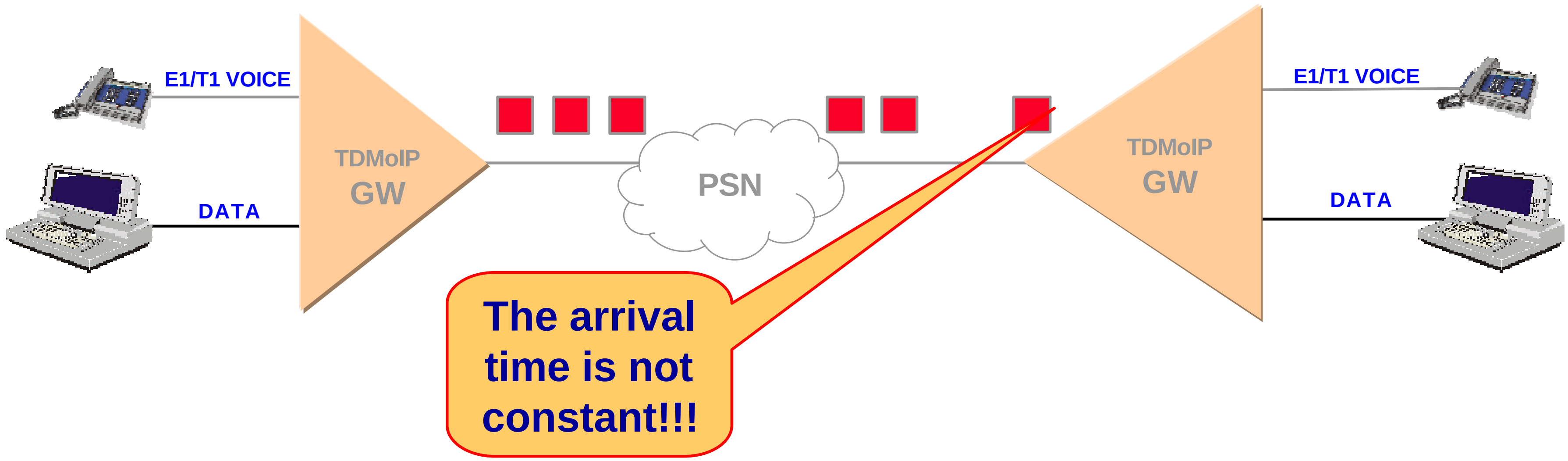
- The synchronous bit stream is chopped into segments
- TDM segments may be *adapted,* but are not compressed
- TDMoMPLS control word is prepended
- Outer and Inner labels are prepended
- Packets are transported over MPLS network to destination
- MPLS labels are stripped
- Control word is checked, utilized and stripped
- TDM is extracted and played out

TDMoMPLS packet format

Outer Label	Inner Label	Control Word	**TDM Payload**

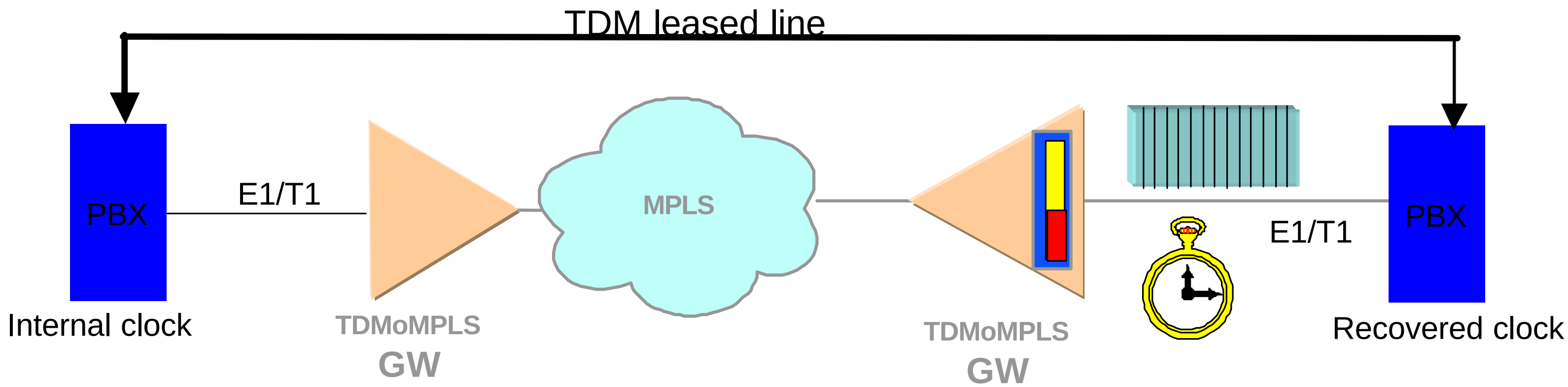
- Inner and outer labels specify TDM routing and multiplexing
  - ✓ Inner Label contains TDMoMPLS circuit bundle number
- Control word
  - ✓ Enables detection of out-of-order and lost packets
  - ✓ Indicates critical alarm conditions
- TDM payload may be *adapted to*
  - ✓ Assist in timing recovery and recovery from packet loss
  - ✓ Ensure proper transfer of TDM signaling
  - ✓ Provide an efficiency vs. latency trade-off

Delay and PDV



- PSNs do not carry timing
- PSNs introduce *delay* and *packet delay variation* (PDV)
  - ✓ Delay = Pure Delay + Buffering to avoid packet loss (PDV)
  - ✓ Delay degrades perceived voice quality

Clock Recovery Required with some Services



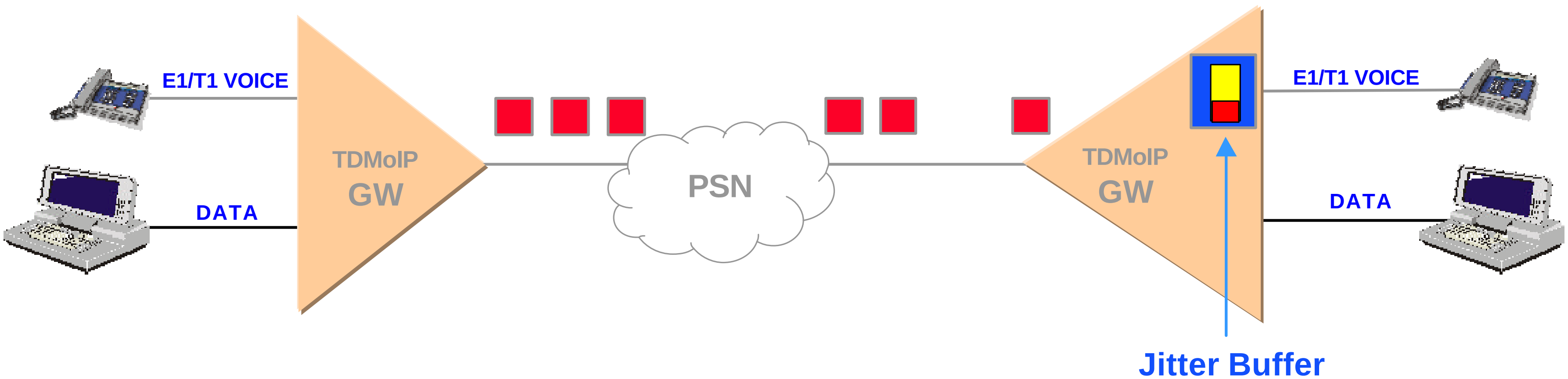
Utilize with service solutions including leased lines which have their own clock

- TDM packets are injected into the MPLS at constant rate
- This rate is determined by the TDM clock
- The network delay can be considered to be a sum of:

  Typical Delay + Random Delay Variation

- By averaging/filtering the random delay can be removed
  - ✓ Averaging typically done by PLL
- Thus the original TDM clock can be recovered

Jitter Buffer

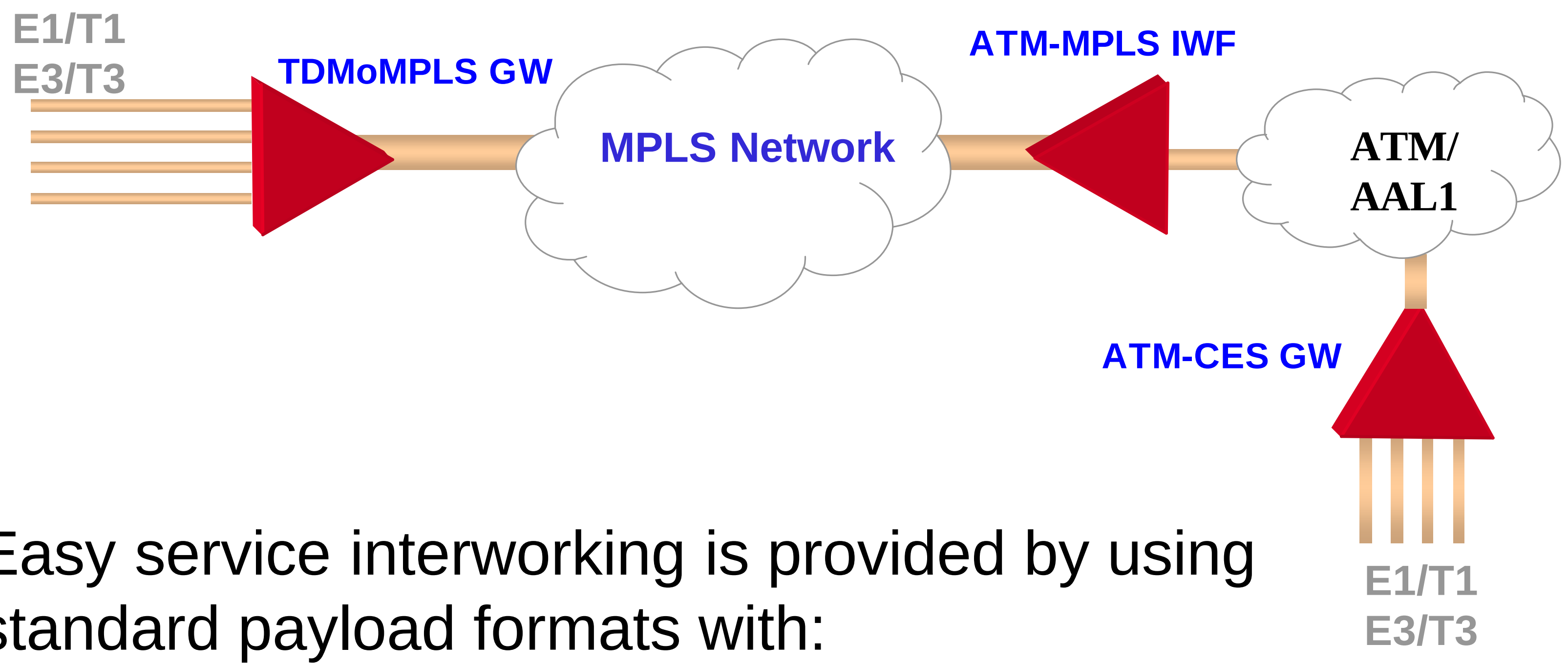


- Arriving TDMoIP packets written into *jitter buffer*
- Once buffer filled 1/2 can start reading from buffer
- Packets read from jitter buffer at constant rate

  How do we know the right rate?

  How do we guard against buffer overflow/underflow?

TDMoMPLS Service Interworking 1 of 2

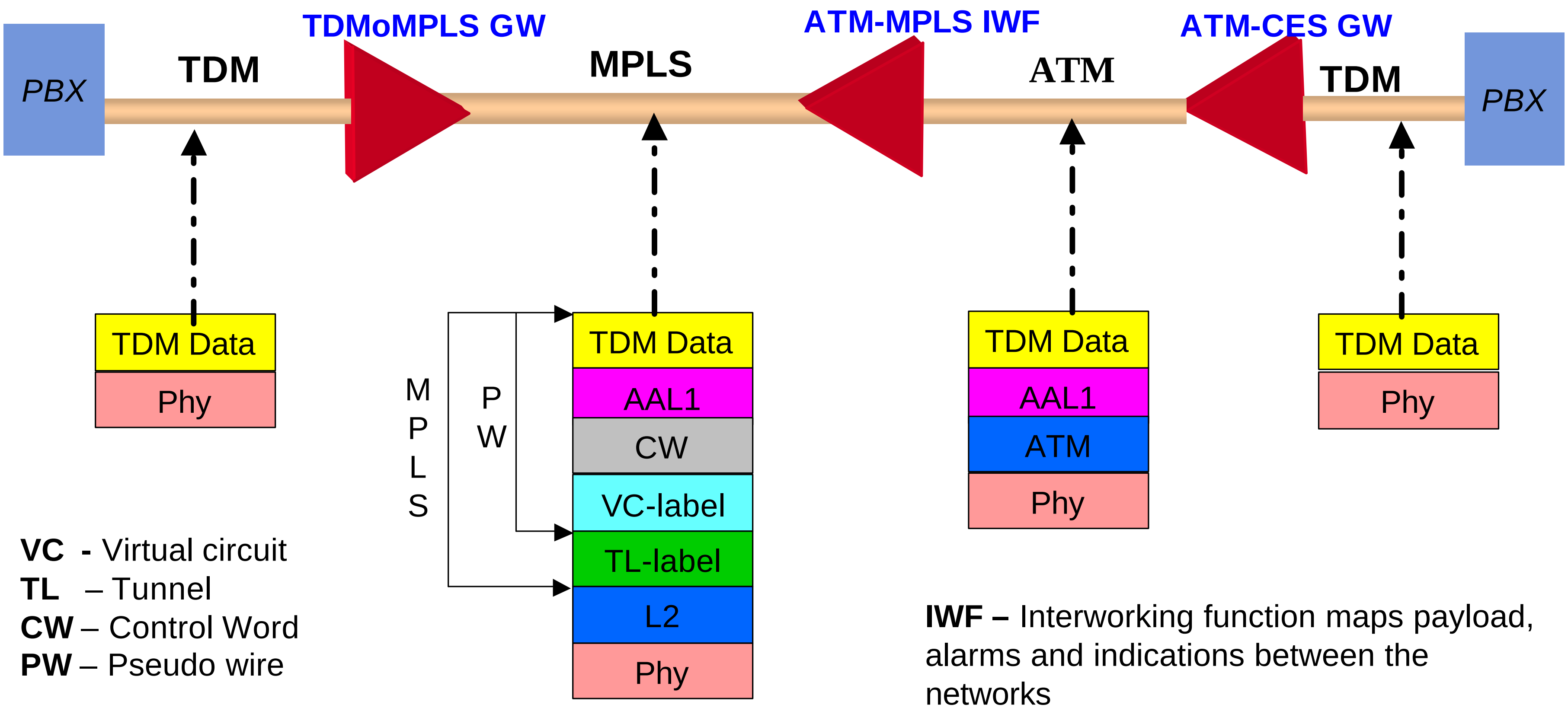


Easy service interworking is provided by using standard payload formats with:

- ATM circuit emulation services (AAL-1)
- Cellular networks (AAL-2)

MPLS & Frame Relay Alliance "TDM Transport over MPLS using AAL1" Implementation Agreement (IA) 4.0

TDMoMPLS Service Interworking 2 of 2



VC - Virtual circuit
TL – Tunnel
CW – Control Word
PW – Pseudo wire

IWF – Interworking function maps payload, alarms and indications between the networks

MPLS & Frame Relay Alliance "TDM Transport over MPLS using AAL1" Implementation Agreement (IA) 4.0

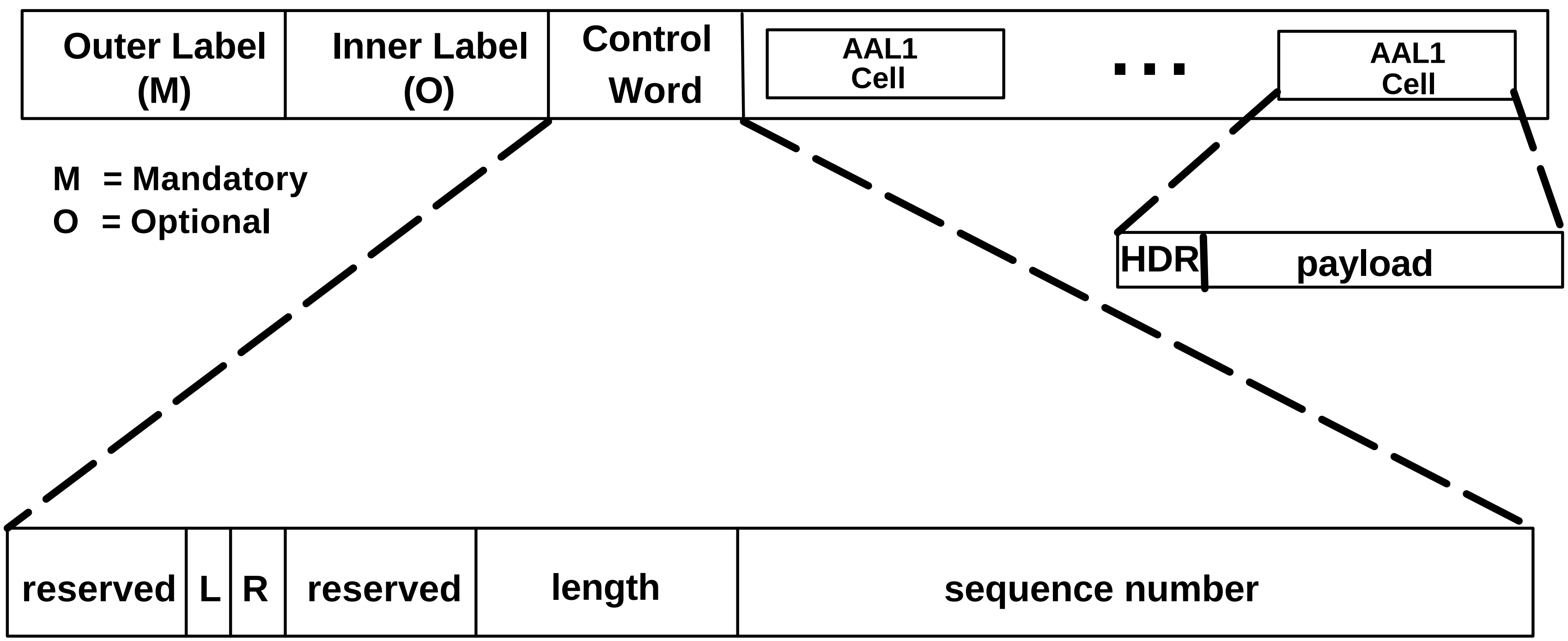
TDM Transport over MPLS using AAL1

MPLS & Frame Relay Alliance TDM Transport over MPLS using AAL1 Implementation Agreement (IA) 4.0

Defines network interworking between TDM circuits over LSPs using AAL1 encapsulation for efficient traffic consolidation with other services on an MPLS network

- Uses standard AAL1 adaptation
- Unstructured and structured transport
- Nx64K, T1, E1, T3, E3 support
- Support for channel associated signaling (CAS)
- TDM alarm indications
- MPLS packet loss monitoring
- Simple interworking with existing ATM-based CES
- Can interwork with ATM over MPLS pseudo wires

Packet Format



L local TDM fault

R remote network failure

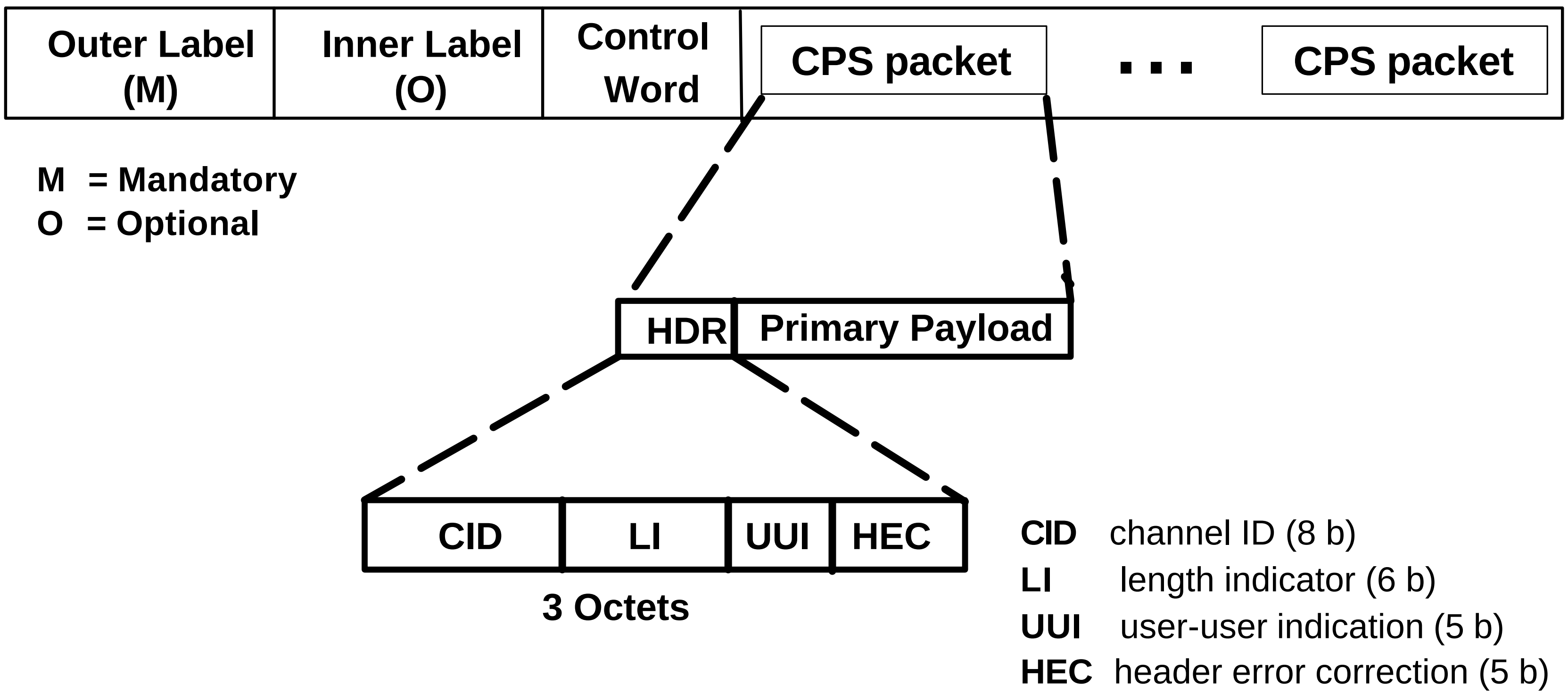
I.366.2 Voice Trunking over MPLS

MPLS & Frame Relay Alliance I.366.2 Voice Trunking Format over MPLS Implementation Agreement (IA) 5.0

Defines an efficient transport mechanism for voice trunking (per format definitions in I.366.2) for traffic consolidation with other services on an MPLS network

- Uses standard AAL2 adaptation
- Dynamic allocation of TDM timeslots
- Suppression of inactive (on-hook) channels
- Support for voice activity detection
- Accommodates voice compression technologies
- TDM alarm indications
- Simple interworking with CID-switches
- Simple interworking with VoMPLS
- Applications: cellular back-hauling, toll-bypass, compressed voice systems (CVS)

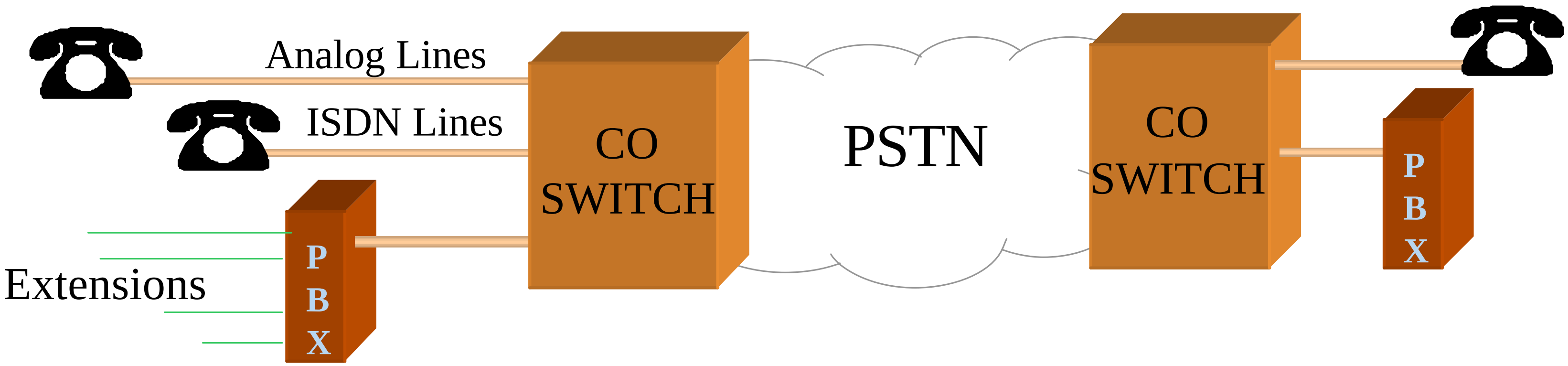
Packet Format



Voice Migration Agenda

- Voice transmission
  - ✓ Characteristics of the TDM and packet voice
  - ✓ Codecs
  - ✓ Delay
- Voice over IP (VoIP), including VoIP/MPLS
  - ✓ Characteristics
  - ✓ Headers
  - ✓ Signaling
  - ✓ Call Admission Control (CAC)
- Voice over MPLS (VoMPLS)
  - ✓ Definition, applications, architecture, characteristics
  - ✓ MPLS tools for voice services
  - ✓ Frame formats for VoMPLS
- Voice migration summary

TDM Voice Characteristics



- TDM voice networks guarantee Grade of Service (GoS) and QoS since there is no statistical multiplexing (i.e. it is circuit switched)
- The Public Switched Telecommunications Network (PSTN) is optimized for voice
- Voice has guaranteed bandwidth and does not compete with data
- Voice quality factors in the PSTN:
  - ✓ Network delay
  - ✓ Echo suppression

Packet Voice Characteristics

- Packet loss in the Packet Switched Networks (PSN) due to
  - ✓ Packet shaping and policing in the access and backbone (managed)
  - ✓ Bit error rate (BER) and router congestion (unmanaged)
  - ✓ Links (Ex: through bandwidth expansion on POS links with HDLC bit stuffing as link nears capacity)
- Packet Delay (PD) due to encoding, packetization and network performance
- Packet Delay Variation (PDV)
- Voice quality factors in the PSN:
  - ✓ PD, PDV
  - ✓ Bandwidth, packet loss
  - ✓ Echo
  - ✓ Compression

Speech Codec Examples

- Waveform codecs, e.g., PCM and ADPCM
  - ✓ Sampling and coding of incoming analog signals
  - ✓ Accurate reproduction of the analog waveform
  - ✓ G.711-PCM (64 kbps); G.726-ADPCM (32/24/16 kbps)
- Code Excited Linear Prediction (CELP) codecs, e.g.:
  - G.723.1 (5.3 kbps), G.729 (8 kbps)
- Multi-Pulse Multi-Level Quantization (MP-MLQ), e.g.:
  - G.723.1 (6.3 kbps)

Observations:

- Multiple encoding/decoding instances increase degradation
- Packet loss affects the quality of encoded voice differently for different compression algorithms

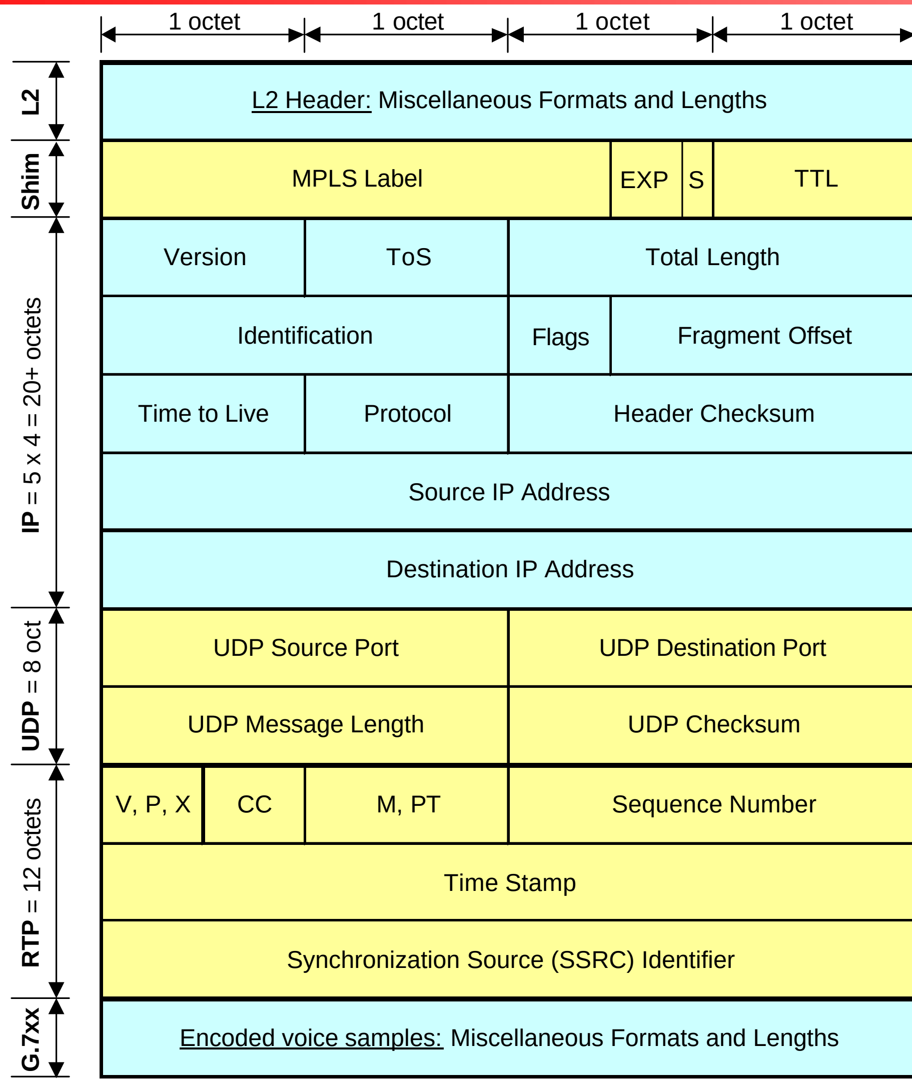
End-to-End Delay

- Components of the end-to-end delay
  - ✓ Transmission delay, e.g., a 80-byte packet over a 64 kbps link takes 10 ms
  - ✓ Propagation delay
  - ✓ Node delay, due to queuing and packet processing, reframing, …
  - ✓ Gateway delay, e.g., speech coding/decoding (codec)
- Codec processing delay
  - ✓ Look-ahead to improve the performance of the compression
  - ✓ Decoder processing and use of an output buffer
  - ✓ Thread delay for processing
- Delay is variable and produces jitter

Voice over IP (VoIP)

- Voice service transported over or delivered from an IP network
- VoIP encapsulation: IP/UDP/RTP/Voice
  - IP+UDP+RTP header overhead is at least 40 bytes
- Header compression may be used to reduce overhead and improve bandwidth efficiency (Ex: VoMPLS in core and pt-pt low speed access links)
- Work in progress in the IETF to improve IP/UDP/RTP header compression

VoIP/MPLS Header Structure



MPLS FORUM

Frame Relay Forum www.frforum.com

BICC in VoIP Networks

- BICC = Bearer Independent Call Control, VoIP signaling mechanism independent of underlying networks, defined by ITU-T
- IP BCP = IP Bearer Call Control, control of VoIP flows in IP networks
- BICC Signaling Entities (SEs) must interact with IP BCP SEs to specify:
  - ✓ Channel attributes
  - ✓ Addressing
  - ✓ Binding information
  - ✓ Cause (i.e., mapping of failure indicators between IP BCP and BICC)

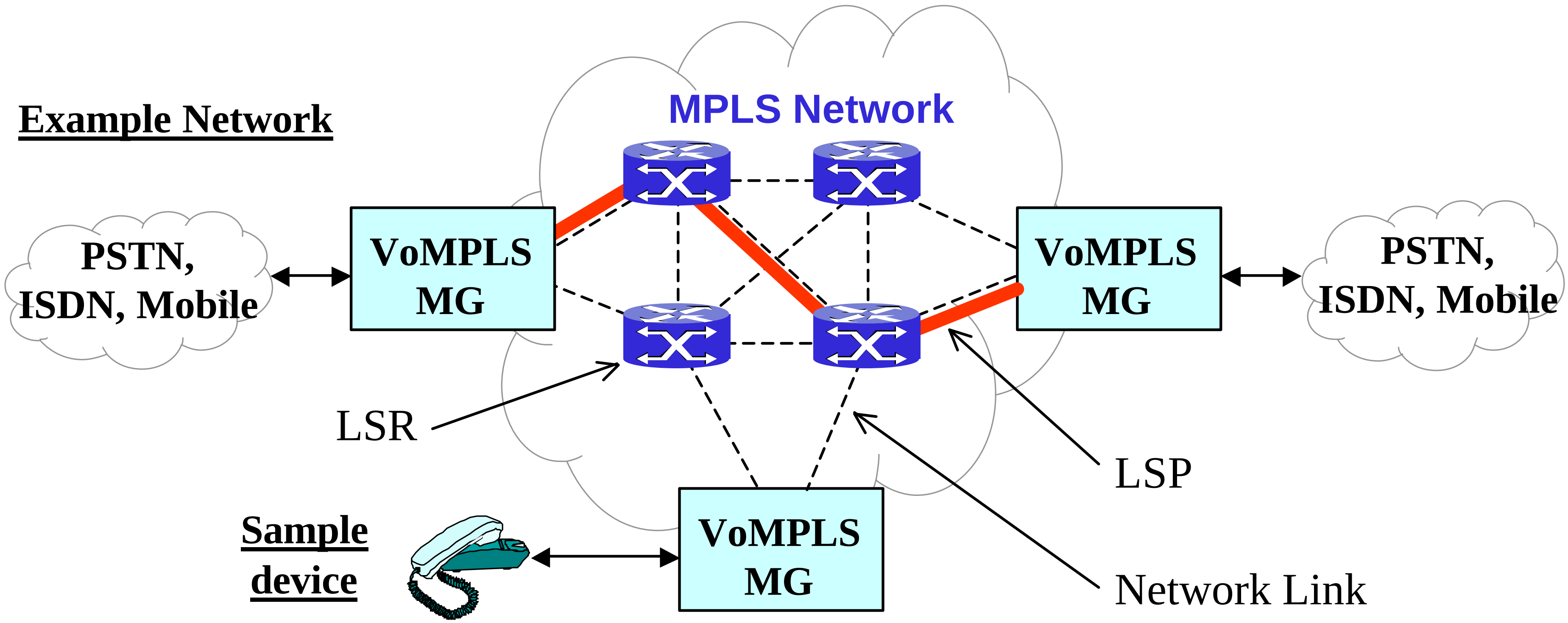
Call Admission Control

- CAC = Call Admission Control, a function in the VoIP networks equivalent to call blocking in the PSTN
- In the IP networks – without CAC – all calls in progress could start experiencing delays and packet loss
- Examples of CAC algorithms:
  - ✓ Exact accounting = on a per-call basis
  - ✓ Inexact accounting = periodic accounting using different thresholds for blocking lower and higher priority calls
  - ✓ Measurements-based = periodic accounting using network probes

Network Applications for Voice over MPLS (VoMPLS)

- VoMPLS is complementary to VoIP <u>and</u> VoIP over MPLS (VoIP/MPLS)
- Used when both source and destination are VoMPLS enabled
- Optimal use in core networks
  - ✓ Using BICC for signalling over an MPLS network
  - ✓ As a trunking application for fixed/mobile access

VoMPLS Architecture



Note: VoMPLS Media Gateway (MG) interworking functions with other networks or devices is not specified in the MPLS & Frame Alliance's IA

Characteristics of VoMPLS

- For access/trunking applications:
  - ✓ Efficient header (4 bytes)
  - ✓ No need for header compression
  - ✓ Voice samples multiplexed in an MPLS frame
  - ✓ Support of different codec types
  - ✓ Support of silence suppression by using Silence Information Descriptor (SID)
  - ✓ Support of the Dual-Tone Multi-Frequency (DTMF) signaling and Channel Associated Signaling (CAS) for a voice channel
- Subset of these for core (between TDM elements) applications

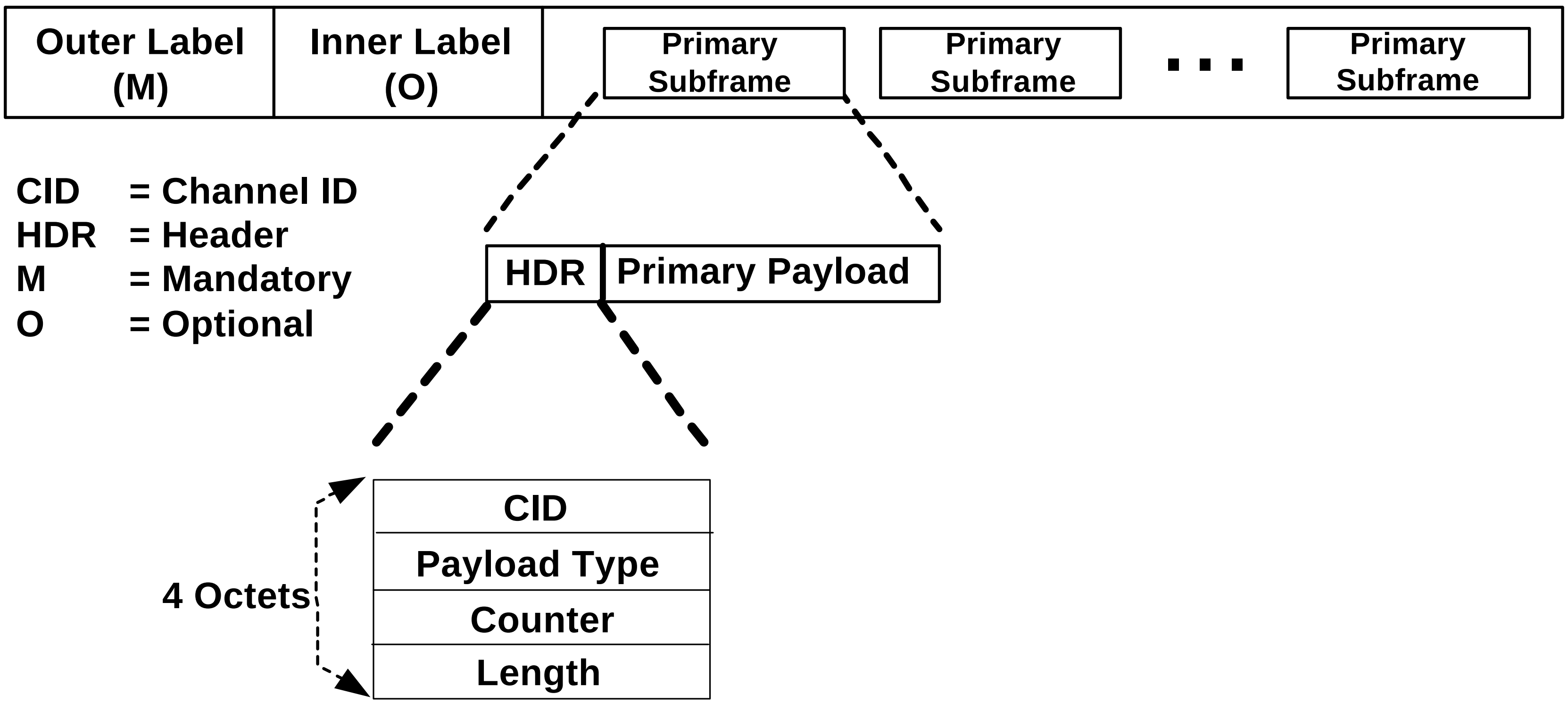
MPLS Features Leveraged for Voice Services – 1 of 2

- Traffic Engineering
  - ✓ LSP engineering to meet latency and loss objectives
- Resource reservation for traffic-engineered paths
  - ✓ Resource reservation on a per-LSP basis
  - ✓ Call Admission Control (CAC) in VoMPLS gateways for voice streams directed to LSPs
- Differentiated forwarding behaviors
  - ✓ Class of Service (CoS) control of scheduling and drop behaviors at the LSP level using E-LSPs and L-LSPs

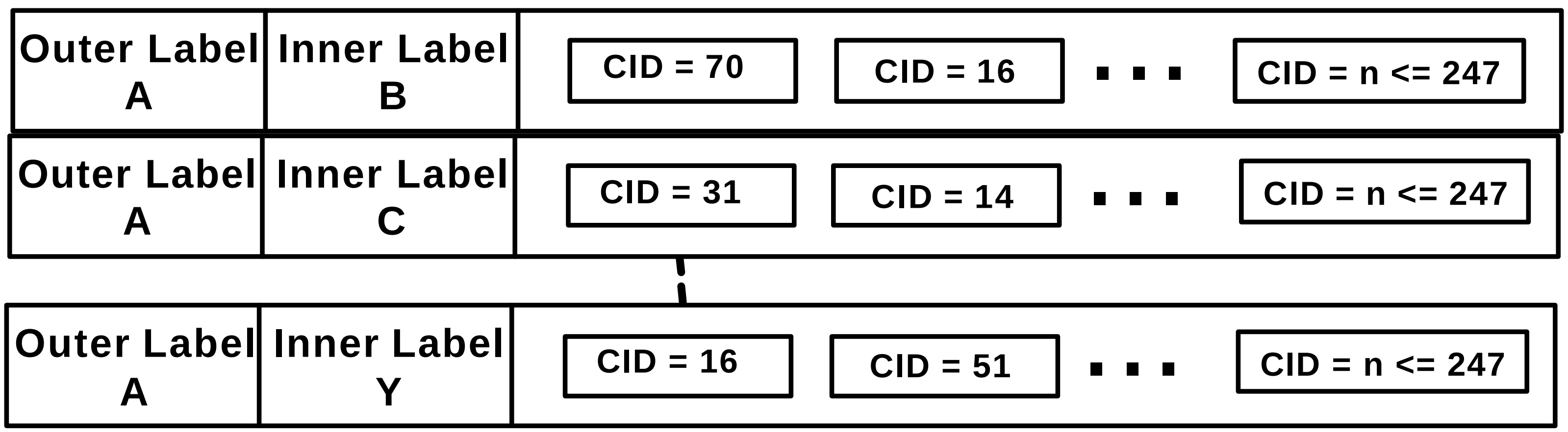
MPLS Features Leveraged for Voice Services – 2 of 2

- Path protection
  - ✓ Use of protected LSPs to meet reliability requirements for a voice service
- Bandwidth efficiency
  - ✓ Elimination of the customary VoIP headers (RTP, UDP, IP)
- Traffic aggregation
  - ✓ Used for scalability and operational simplicity
- Label stacking
  - ✓ Used to distinguish mandatory outer labels from the optional inner labels
  - ✓ Other common stacking applications (e.g., recovery, aggregation)

LSP Structure for Primary Subframes



Stacked-LSP Structure for Multiplexing



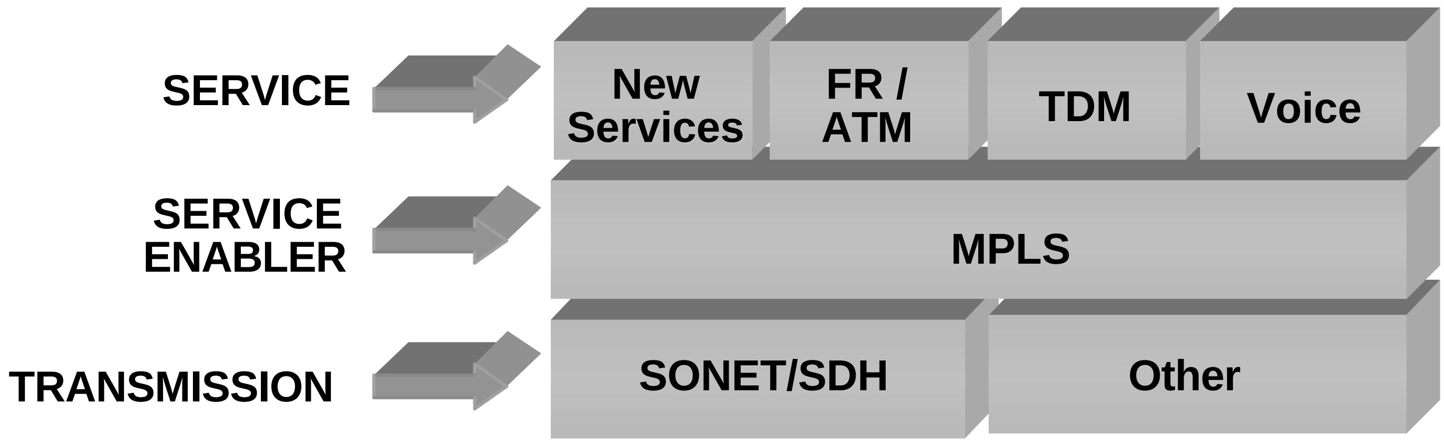
Summary of Voice Migration

- Service convergence leads to voice encoding and its transport over data networks
- Voice encoding presents a new set of challenges
- VoIP is suitable when end stations are VoIP capable; VoIP packets can then be transported over MPLS networks as VoIP/MPLS
- VoMPLS provides direct encapsulation of voice samples without RTP/UDP/IP headers and thus increases efficiency
- VoMPLS is suitable for trunking applications between gateways
- VoMPLS is defined by the MPLS & Frame Relay Alliance

End of Session 5

Thank You

Migrating Legacy Services to MPLS Summary



- Frame Relay, ATM, TDM and Voice Services can today leverage an MPLS infrastructure for increased solution capabilities, flexibility and reduced cost
- Emerging industry standards/agreements from groups such as the MPLS & Frame Relay Alliance are supplementing IETF and ITU-T work in critical areas for profitable legacy services support with MPLS

For More Information. . . . .

- http://www.mplsforum.org
- http://www.frforum.com
- http://www.ietf.org
- http://www.itu.int
- http://www.atmforum.com
- http://www.mplsrc.com

For questions utilize the MPLS & Frame Relay Alliance Message Board

Website: http://www.mplsforum.org/board/

Migrating Legacy Services to MPLS

Thank You

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